

EARLY NUMERACY INTERVENTION: DOES  
QUANTITY DISCRIMINATION REALLY WORK?

By

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WORK?

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Title of Study: EARLY NUMERACY INTERVENTION: DOES QUANTITY  
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Abstract:

Scope and Method of Study: The current study demonstrates that a taped problem intervention is an effective tool for increasing the early numeracy skill of QD. A taped problems intervention was used with two variations of the quantity discrimination measure (triangle and traditional). A 3x2 doubly multivariate multivariate analysis of variance was used to analyze the pre/post data across time and group on each assessment measure.

Findings and Conclusions: Findings indicated that the both forms of the quantity discrimination measure are useful assessment measures for student progress however intervening on these skills does now generalize across more complex math skills.

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## CHAPTER I

### **Introduction**

Proficiency of math facts is a crucial skill that all students should acquire throughout their early school years. According to the National Assessment of Educational Progress (NAEP), students' math performance has moderately improved over the last 20 years; as of last year 60% of fourth graders and 65% of eighth graders perform at or above the proficient level (Aud S., 2011). A study by Cawely et al. (1998) looked at math computation of typically achieving students as compared to students diagnosed as learning disabled. In total 229 9 to 14 year-olds were examined, finding that just 81% of 14-year-olds had mastered addition, while 85% had mastered subtraction, and only 54% had mastered multiplication and division. Proposing a significant number of students have not yet mastered basic calculation skills by the age which they are beginning high school (Cawley, Parmar, Yan, & Miller, 1998).

Math scores among United States youth, though showing improvement, currently rank the U.S. below the top ten countries worldwide. This signifies a substantial problem, since it is expected that students master basic calculation skills by the fourth grade (Shapiro, 2004). Basic Calculation skills have been found integral for success while participating in academic, occupational, and daily living activities (Patton, Cronin, Bassett, & Koppel, 1997).

U.S. mathematics performance suggests that competency of calculation is an ever increasing nationwide issue. There are smaller subsets of students for whom deficits in mathematics are also a concern. Among students with learning disabilities in the United States as many as 10% have also been diagnosed with a mathematics learning disability (MLD) (L. S. Fuchs et al., 2005). When looking at students who have been classified as learning disabled 50% have mathematics related items on their Individual Education Plans (Kavale & Reese, 1992). Students with MLD subsequently perform at lower levels than their learning disabled-only peers, but also show more limited progress than typically performing students (Cawley, et al., 1998). This places these students at higher risk for negative academic and occupational outcomes.

Dysfluent calculation is a distinguishing characteristic of children who have math difficulties (MD). Knowledge of number combinations, position and magnitude is important when solving math problems. Performing higher order computations using multi-digit numbers relies heavily on fluent knowledge of number combinations. A child with weak abilities to consolidate number combinations and basic math facts may have reduced cognitive and attentional resources, necessary for higher-level problem solving (Goldman & Pellegrino, 1987).

Students often utilize time-consuming counting strategies (i.e. finger counting and tally marks) when solving basic math problems (McCallum, Skinner, Turner, & Saecker, 2006). These strategies enable the student to answer accurately, however, these strategies often limit the student's fluency (Ysseldyke, Thill, Pohl, & Bolt, 2005). Students who are capable of completing math facts fluently have more cognitive resources available for learning higher order computation skills (Samuels, 1994). This has created a need for developing a way to better teach these students how to accurately and fluently answer math problems.

The No Child Left Behind Act (NCLB) was put in place to seek out and improve the educational achievement of students in the United States in 2001. The NCLB has stressed accountability amongst

educators in schools and making academic assessment a prominent issue (Congress, 2002). The President's Commission of Excellence in Special Education has highlighted early identification of academic difficulties and early intervention as fundamental factors for improving student achievement (*President's Commission on Excellence in Special Education*, 2001). The use of Curriculum Based Measurement (CBM) in primary grades (i.e. kindergarten and first grade) is one way for schools to meet these new accountability requirements. The application of CBM is a simple way to assist in early identification and develop interventions focused on emerging math skills.

Curriculum Based Measure is a progress monitoring and assessment tool used to specifically measure individual academic skills. CBM was developed with unique characteristics differentiating it from other types of assessment measures. CBM is brief, simple to administer, matched to curriculum, and most importantly, sensitive to short-term growth (Bieber & Choi, 2004). These unique characteristics ensure CBM measures meet criteria stated in the President's Commission on Excellence in Special Education (2001). Enabling educators to incorporate formative assessment techniques that inform the instructional and intervention practices in classrooms across the United States (*President's Commission on Excellence in Special Education*, 2001).

Research over the last 40 years has provided support for CBM as a reliable and valid assessment approach for evaluating elementary level academic skills (Shapiro, 2004; M. R. Shinn, 1989). Mathematics-CBM (M-CBM) has been researched less frequently amongst the early elementary grades as compared to other CBM measures (i.e. reading). Three main areas encompass M-CBM: (a) computation/operations, (b) applications/problem solving, and (c) early numeracy skills. Early numeracy skills include identifying numbers, counting, and knowledge of number magnitude and position. M-CBM is frequently researched for validity (Foegen, Jiban, & Deno, 2007; Skiba, 1986), reliability (L. S. Fuchs, Fuchs, Hamlett, & Stecker, 1990; Tindal, 1983), and has been proven useful to progress monitor student performance over short periods of time (L. S. Fuchs, Fuchs,

Hamlett, & Stecker, 1991). These properties make M-CBM uniquely beneficial tool for assessing student performance and progress monitoring during intervention.

Number sense theory and M-CBM measures provided the framework for Early Numeracy CBM (CBM-EN) measures (counting, number naming, number writing, skills associated with number line knowledge, and the ability to make judgments about quantities) were developed. The National Committee of Teaching Mathematics (NCTM) proposed that pre- students should be competent in understanding numbers, mental representation of numbers, and relationships among numbers and number systems by completion of second grade (Mathematics, 2000a).

The objective of CBM-EN has been to identify brief, repeatable measures which are reliable and valid, and can be used to inform instructional decisions in schools. CBM-EN research has identified several measures that correspond to significant number sense concepts (counting, naming and identifying numbers, comparisons of magnitude, using number lines, and discriminating among numbers and shapes) (Foegen, et al., 2007; R. Gersten, Jordan, & Flojo, 2005; Locuniak, 2008). Familiarity of position and magnitude of numbers along with the ability to manipulate quantities are keystone accomplishments used to predict later math computation skills (Mathematics, 2000a).

CBM-EN concepts are based off of the Tests of Early Numeracy (TEN). Identified measures are Oral counting (OC) (having the student count aloud from 1-100), Number Identification (NIM) (having the student id numbers 1-20 on a grid for first grade), Missing Number (MNM) (having the student id which number is missing from a pairing 3\_\_5, and the student would give 4 as the answer), and Quantity Discrimination (QD) (having the student identify which number out of a pair of numbers is larger).

Introductory studies have shown CBM-EN possess adequate reliability, validity, and sensitivity amongst pre-school through first grades (Chard et al., 2005; Clarke & Shinn, 2004; Daly, Wright, Kelly, & Martens, 1997; Locuniak, 2008; VanDerHeyden, Broussard, & Cooley, 2006;

Vanderheyden et al., 2004). VanDerHeyden et al. (2006) investigated long term predictive validity of CBM-EN concepts following students from Pre-school to First grade. These findings suggest that from pre-school to kindergarten, student performance is moderately to strongly correlated. During these years students typically make noteworthy growth. There is also evidence supporting the importance of preschool measures for identifying children in need of intervention during Kindergarten and even First grade (VanDerHeyden, et al., 2006).

Locuniak and Jordan (2008) identified Counting, Quantity Discrimination, Nonverbal calculation, story problems, and number combinations as primary predictors of calculation fluency amongst Kindergarten age students. Screening in kindergarten, using "at-risk" versus "not-at-risk" criteria, 84% of the children were identified who did not go on to have calculation fluency difficulties. These criteria positively identified 52% of the children who went on to later have math fact fluency difficulties in 1<sup>st</sup> and 2<sup>nd</sup> grade (Locuniak, 2008).

Clarke & Shinn (2004) used the Woodcock-Johnson Tests of Achievement to assess predictive validity of CBM-EN amongst 52 first grade students. Their findings indicated NIM having a correlation of .72, MNM .72, and QD as the best (.79) for spring of first grade when compared with the Woodcock-Johnson Tests of Achievement (Clarke & Shinn, 2004).

Martinez et. al. (2009) tested the Technical Adequacy of CBM-EN in kindergarten. A total of 59 kindergarten students took part in the study. Aims-web CBM-EN measures (OC, NIM, MNM, and QD) were used (Clarke & Shinn, 2004). These measures were compared with the Stanford 10 Achievement Test (SAT-10). CBM-EN measures were collected in the fall, winter, and spring for all of the students during the schools regular benchmark periods. Predictive validity scores between the fall administration and the SAT-10 are as follows: OC was .45( $p<.01$ ), NIM was .31 ( $p<.05$ ), QD was .46 ( $p<.001$ ), and MNM was .36 ( $p<.05$ ). Results indicated that during First grade QD was the best predictor of SAT-10 scores in the fall, and in the spring was found to be the solitary predicting

variable for SAT -10 scores ( $R^2=.33$ ),  $F(7,37)=4.11$ ,  $p=.002$ . Students showed an average increase of .32 digits correct per week on QD from fall to spring administration. Among students, for every 1-point increase on the QD-CBM measure, SAT-10 standard scores increased an average of 2.6 points between kindergarten and 2<sup>nd</sup> grade. (Martinez, Missall, Graney, Aricak, & Clarke, 2009). Current research has indicated QD having generated the strongest evidence for conventional reliability and predictive validity among kindergarten and first grade students, over all other CBM-EN measures.

Chard et al., (2005) explored the predictive validity of three CBM-EN screening measures (NIM, MNM, and QD) using a larger sample size. Correlates for the fall and spring performance for both kindergarten and first grade were calculated using the Number Knowledge Test (NKT) instead of the Woodcock-Johnson. The NKT was chosen because it is a stronger screening measure when compared to the Woodcock-Johnson III Tests of Achievement (Okamoto & Case, 1996). Kindergarten scores indicated the following correlations QD .45, NIM .56, and MNM, .61, First grade correlations were QD .53, NIM, .58 and MNM, .61 during the spring assessment (Okamoto & Case, 1996).

Lembke et al. used the Stanford Early School Achievement Test (SESAT; Psychological Corporation, 1996) was used to assess criterion validity of CMB-EN measures (QD, NIM, and MNM) among first grade students in the fall. MNM has the lowest validity coefficient at .21, followed by NIM at .47, and the highest was QD at .50 when compared with the SESAT in the fall of first grade (Lembke, Foegen, Whittaker, & Hampton, 2008). This data supports previous and current CBM-EN research identifying QD as the strongest predictor of math fluency among first grade students.

Jordan et al. (2007) found that Number Sense measures accounted for 66% of the variance in predicting math achievement from Kindergarten to First grade. Quantity discrimination had the strongest correlations at each assessment time (Fall, Winter, and Spring) with a median correlation of

.54 with the Woodcock Johnson III Achievement tests of calculation and fluency (Jordan, Kaplan, Locuniak, & Ramineni, 2007). Quantity discrimination was measured both in the original form (identifying the larger number given two numbers in a box) and the triangle form (identifying which number is closer to the number at the top of an equilateral triangle).

Locuniak and Jordan (2008) looked at the skill of QD, using an equilateral triangle instead of the traditional measure. Students were asked to identify which number was closer to the number at the top of the triangle. Digit span forward and backward, basic calculation fluency and vocabulary were also measured. Scores from these measures were used to determine their predictability of Second grade math calculation (Locuniak, 2008).

A two model regression determined which measures accounted for the highest predictive validity of math calculation from Kindergarten to 2<sup>nd</sup> grade. When age, reading, and general cognitive measures are accounted for, quantity discrimination is responsible for 16% of the predictive variance. The second closest predictor was 1x1 computation skills which accounted for 14% of the predictive variance. Student's demonstrated a .86 increase in calculation fluency for every 1 point increase in quantity discrimination, and a .57 increase in calculation fluency for every 1 point increase on 1x1 computation (Locuniak, 2008). Quantity discrimination predicted calculation fluency over and above general predictors.

This research has provided further support for the importance of assessing quantity discrimination and its unique importance as an early screening measure. Students entering First grade differed in their ability to answer quantity discrimination questions such as, "Which number is bigger, 5 or 4?" even when student abilities of counting and simple computation have been controlled. Intervention in first grade on more complex early numeracy skills such as quantity discrimination, may allow students to quickly catch up with their peers.

Good and Brophy (1986) suggested early intervention and evaluation of early numeracy skills leads to increases in student math achievement (Good, 1986). Supporting the current emphasis that professional's should use CBM-EN tools for progress monitoring, intervention, and assessment of primary elementary grade students. Performing early intervention is crucial and reduces the severity of learning difficulties. Given the novelty of current research, it is important to continue the investigation of CBM-EN measures, to identify new measures which may tap into new areas of number sense not previously considered.

More-over, number sense and specifically QD during Kindergarten and 1st grade is highly correlated with and predictive of math achievement in 2<sup>nd</sup> grade. Recent research has demonstrated how number sense measures relate in particular to math fact fluency, a definitive marker for MLD in second grade and beyond. Mastery of numerical magnitudes should allow students to internalize and master basic math facts and number combinations more rapidly in early elementary grades.

In summary quantity discrimination is an essential conceptual structure of number that affects many links among mathematical relationships, principles, and procedures. These links in procedural knowledge are necessary for students to build fluent and complex math skills. Fluency will allow students to quickly develop higher order procedures. In 6 and 7 year-olds, two components of number sense are necessary (counting and quantity discrimination). These skills need to be well linked for a student to become proficient at mathematical thinking and computation.

The purpose of this research is the development of an effective early numeracy intervention, which can be used in early childhood programs by teachers to assess and increase the ongoing development of mathematical understanding and early numeracy skills. I aim to find whether intervening on the robust skill of quantity discrimination among first grade students will increase their math computation fluency and overall mathematical thinking.



Research Question #1 Which taped problems intervention will lead to the greatest learning rates amongst first graders?

Research Question #2 Which taped problems intervention will lead to the greatest increase on student's early numeracy skills?

Research Question #3 Will providing a taped problems intervention on traditional and triangle quantity discrimination, increase a child's calculation fluency?

Research Question #4 Will providing a taped problems intervention on traditional and triangle quantity discrimination increase a student's math knowledge?

## CHAPTER II

### LITERATURE REVIEW

#### **Related Literature**

As the previous chapter indicated, national statistics (NAEP, 2005) demonstrate a need for improvement in mathematics competency among students on the U.S. Specifically more students should be performing in the proficient, above range, and average range. Fewer students should be getting identified at the below basic level. Supporting national efforts to enhance mathematics knowledge and skills in school-age children needs to be a primary effort for teachers, psychologists, and researchers in the field of education.

A study by Cawely, Parmar, Yan, and Miller (1998) investigating arithmetic computation of typically achieving students and students with learning disabilities, has provided support that students' mathematics skills are lacking. When the authors examined computational performance of 229 normally achieving 9 to 14 year-olds, they found that just 81% of typically achieving 14-year-olds had mastered computational addition, while 85% had mastered subtraction, and only 54% had mastered computational multiplication and division. From this study it is evident that a substantial number of students have not mastered basic arithmetic computation skills by the age at which most students are preparing to enter high school (Cawley, Parmar, Yan, & Miller, 1998). These results signify a considerable problem, since it is expected that students master basic computational skills by the fourth grade (Shapiro, 2004) and because basic arithmetic skills are so

often essential to academic, occupational, and daily living activities (Patton, Cronin, Bassett, & Koppel, 1997).

Gonzales (2004) reported fourth grade comparisons made among students from 25 countries and eighth grade comparisons made among students from 45 countries to see how U.S. students compared to their international peers. The data used to make these comparisons included performance on math and science assessments developed for the Trends in International Mathematics and Science Study (TIMSS), student, teacher, and principal responses to questionnaires related to student's schooling and learning experiences. Findings illustrated that, while U.S. fourth and eighth grade students scored above the total international averages in mathematics and science, they continued to perform below a number of countries.

U.S. fourth grade students' scored lower than the average mathematics score of countries such as Singapore, Hong Kong, and Japan, as well as European countries including the Netherlands, Latvia, England, and Hungary. With respect to eighth grade math performance, U.S. students performed, on average, below seven countries including some of those who outperformed U.S. fourth graders. Although the increased performance by eighth grade students is encouraging, U.S. eighth grade students performance remained similar from 1995-2003. Additionally fourth grader's relative international standing in mathematics decreased over this time period (Gonzales, 2004).

In an international study, the Program for International Study Assessment (PISA) reported even more troubling findings. Forty-one countries participated in PISA, a study examined 15 year-olds abilities in reading, mathematics and science literacy every three years. According to Lemke et al., PISA findings showed that U.S. 15 year-olds' average performance in mathematics and problem solving was lower than the international averages. More specifically, 23 countries outperformed the U.S. in terms of average combined math scores and 25 countries

outperformed the U.S. in terms of average problem solving scores. The U.S. had a greater percentage of students in the lowest proficiency than any other country. U.S. students may face challenges in using mathematics on a day to day basis which raise apt concerns about the future ability of the U.S. to compete in the global marketplace (Lemke, 2004).

### **Math Learning Disabilities**

While U.S. students' mathematics performance suggests that competency in mathematics is a critical issues for our nation as a whole; there are smaller subsets of students for whom deficits in mathematics are also a concern. As many as 4%-7% of students are identified in the United States with some form of mathematics learning disability (MLD) (L. S. Fuchs, et al., 2005). As many as 50% of students classified as learning disabled have mathematics related items on their Individual Education Plan (IEP) (Kavale & Reese, 1992).

Students with MLD not only perform at lower levels than their non-disabled peers, but also show more limited progress than typically performing students (Cawley, et al., 1998). This places these students at greater risk for negative academic and occupational outcomes (M. M. M. Mazzocco & R. E. Thompson, 2005). The *Diagnostic and Statistical Manual of Mental Disorders* (DSM-IV-TR); provides a definition, based on a discrepancy between ability and achievement. Mathematics Disorder (MD) is one Learning Disorder (LD) that may appear in childhood. The essential feature of MD is mathematical ability that falls substantially below that expected for the child's age, intelligence, and age-appropriate education. Furthermore, the disturbance in mathematics must significantly impair the student's academic achievement or interfere with activities of daily living that require mathematical skills. Finally, if there is a sensory deficit present, the difficulties in mathematical ability must be in excess of those usually associated with the sensory deficit. (Association, 2000).

The DSM-IV-TR states that MD may appear as early as kindergarten or first grade, for example, in the form of counting difficulties or confusion in number concepts. Research supports this notion and suggests that difficulties with mathematics may appear as early as first grade in the form of holding information in short-term memory while counting and poor conceptual understanding of counting (Geary, 2004).

Students can perform inconsistently however, on achievement testing across successive academic years, complicating understandings of the course of mathematics difficulties and whether or when a diagnosis of MD is warranted (Geary, 2004). In cases where MD exists, outcomes can be severe, Several sources state that students with LD are at greater risk for dropping out of school and if difficulties persist into adulthood, problems with employment and social adjustment may also surface (Association, 2000; M. I. M. Mazzocco & R. E. Thompson, 2005).

Despite the multitude of definitions of MLD, there seems to be some consensus on how the disorder manifests, for instance, Gersten, Jordan, and Flojo (2005) explain that deficits in many number sense skills, such as counting and performing mental mathematics, are associated with MLD. More specifically, students with mathematics difficulties have poor counting strategies and struggle with retrieving basic math facts, hampering their ability to understand more complex algebraic concepts. The DSM-IV-TR also notes that a number of skills may be impaired in MLD including: linguistic skills (naming mathematical codes or concepts), written math problems, perceptual skills (recognizing symbols and signs), attention skills (paying attention to arithmetical signs), and mathematical skills (following sequences, counting, and learning mathematics facts). Students with MLD may also develop time consuming strategies (finger counting and tally marks) and retrieve math facts less accurately (Hale, 2004).

## **Early Academic Intervention in Mathematics**

Recent legislation such as No Child Left Behind (NCLB 2001), Individuals with Disabilities Education Improvement Act (IDEIA 2004), and current researcher (e.g., Clarke & Shinn, 2004, Fuchs et al. 2005, and Gersten et al., 2005) have highlighted early intervention and progress monitoring as a key component for improving mathematics performance and increasing accountability within schools. The National Joint Council on Learning Disabilities (NJCLD, 2005), The National Council on Teaching Mathematics (Mathematics, 2000a), and The President's Commission on Special Education (2002) all emphasize prevention, screening, identification, and intervention for students who demonstrate early academic difficulties.

Progress monitoring, a type of formative assessment, is included in the aforementioned recommendations. This assessment provides teachers with an accurate measure to assess whether students are benefitting from core curriculum, responding to intervention, and determining if student interventions need intensified reduced. It has been proven that, early identification, intervention, and formative assessment of student progress cumulate three valuable components for increasing general academic outcomes among struggling students (Good, 1986).

Research looking into early math intervention has begun to demonstrate that intervention efforts targeting mathematics difficulties in the primary grades has the prospective of improving student academic performance (L. S. Fuchs & Fuchs, 2001). Dev, Doyle, and Valente (2002) collected data from eleven first grade students identified as at risk by their teacher for reading and mathematics. All students participated in two commercially available intervention programs for mathematics and reading, The Orton-Gillingham and Touch-Math Systems. Students were assessed using the Wide Range Achievement Test-III (WRAT-III) on a pre-post-test basis. The students showed significant gains in academics so much so, that these students considered to be at

risk in the fall of first grade were no longer in need of individualized services in the spring of the second grade (Dev, Doyle, & Valente, 2002).

Gersten et al. (2005) found using strategies from the Number Worlds curriculum (S. Griffin, 2004), (counting upwards from a given number, counting backwards, and linking adding and subtracting to the manipulation of objects), are techniques which are easily implemented into schools core curriculum and has shown to improve number sense and build math vocabulary among students in primary grades (R. Gersten, Jordan, & Flojo, 2005).

Current curriculum in schools requires that teachers teach more than the just the basics of academia (reading, writing, and arithmetic). Time in the classroom is also allocated for teaching self-esteem, building social skills, running alcohol and drug prevention programs, and so forth. The pressure for schools to implement behavioral prevention and intervention programs makes it almost impossible, for teachers to dedicate additional instructional time for improving mild academic skill deficits. Research has shown that interventions requiring extra time and resources are viewed as unacceptable by teachers (Witt, Elliott, & Martens, 1984).

One stimulus control procedure that provides for increasing instructional control is time delay also known as Taped Problems (TP). Taped Problems interventions have the student listen to an audio recording of a series of math problems. The student is instructed to write the answer on the math work sheet before the recording provides the answer for each problem until the tape has finished (Poncy & Skinner, 2006). If the student writes an incorrect response, the student is instructed to replace it with the correct response. If insufficient time is provided for the student to answer, they are instructed to write in the answer once it is heard and work on the next problem. This procedure helps to increase both fluency and accuracy of math problems.

Touchette (1971) first described TP as an errorless learning technique known as “time delay transfer of stimulus control” (Touchette, 1971). A variety of procedures have since been developed and researched in order to better assist students in achieving fluency in mathematics.

Time-delay procedures use brief delays (0 seconds to 2 seconds) to discourage and prevent students from employing time-consuming counting strategies

Taped Problems are intervention procedures that used in schools, across multiple settings. McCallum et al. 2006 used a multiple probe design across tasks varying time delays, (4 second delay, 2 second delay, and no-time delay). This was performed among third grade students focusing on multiplication facts to 9. It was found that on average students' performance doubled (7.5 to 14.7 digits correct) during the 6 weeks of intervention (McCallum, Skinner, Turner, & Saecker, 2006).

Coleman et.al. (2006) have suggested that the earlier we recognize and intervene upon vulnerable students, the more likely we will be able to support their subsequent development and prevent learning difficulties from occurring later on (Coleman, 2006). With evidence that early intervention improves outcomes for students, it is important to identify students who would benefit from these intervention programs. Clarke and Shinn (2004) have recommended that teachers and staff identify students at risk as soon as possible; allowing schools to maximize their effectiveness (Clarke & Shinn, 2004). This being understood, the first step toward improving student performance in mathematics is to identify students quickly and accurately. One common theme that pervades the research on early intervention in mathematics is the need for assessments which can be used to identify struggling students and progress monitor interventions. Dowker (2005) stated: "the most important conclusion that can be drawn from research on early intervention in mathematics is that it is critical to identify early indicators of mathematics in order to improve and prevent later mathematics difficulties" (Dowker, 2007).

Several types of research have been and are currently being undertaken related to mathematics learning in young children. In the beginning Piagetian theory and its contributions to mathematics education are the most prominent theories (Inhelder & Jean, 1964; Piaget, 1952, 1968; Piaget & Szeminska, 1941). Piaget postulated that logical abilities, primarily 'seriation'



(the ability to sort a number of objects based on differences on one or more dimensions while ignoring the similarities), 'classification' (the ability to sort those objects based on their similarities on one or more dimension, making abstraction of the differences) were the first steps in a child's developing logic (Piaget & Szeminska, 1941). Once a child has mastered seriation and classification, they can further develop the knowledge that a number of objects in a collection only changes when one or more objects are added or removed. This concept in logical thinking is called conservation. These three abilities are considered paramount in the development of mathematical thinking.

A second theory, moving beyond Piagetian theory, is a result of descriptive research into specific mathematical concept areas (counting, addition, subtraction) (Koehler & Grouws, 1992). More recently based on these theories, researchers have begun to attempt designing mathematics assessment measures for young children (Clements, 1984; Malofeeva, Day, Saco, Young, & Ciancio, 2004; Vanderheyden, et al., 2004). These strands of research have important implications for the design of curriculum based measurement amongst preschool through first grade children which will be described later in this chapter.

Current research has demonstrated naturally occurring math abilities of preschool children at home and in child care centers is limited. Suggesting young children have limited exposure to mathematical concepts in both the home and child care settings. This implies a further need for measures which allow teachers to quickly and accurately assess student's current level of math knowledge at the beginning of school (Tudge & Doucet, 2004). This assessment information would allow teachers to shape their curriculum, filling in the areas in which their students may be lacking. The order in which children are taught and learn particular content is important for their instructional development in the classroom.

## Number Sense

Research on the psychological development of students in the primary grades, has had significant implications in determining which skills to measure in order to identify students who might be at risk, and which would benefit from early intervention. Beginning research by Kami and Piaget identified several logical abilities conditional to the development of arithmetic: seriation, classification, and conservation of quantities (C. Kamii, 1982; Piaget & Szeminska, 1941). Modern research has extended these principals. The current theory of number sense, in particular, has become important in efforts to identify keystone mathematic skills. Researchers still are in debate on a formal definition of number sense, although, commonalities exist among definitions that are currently accepted.

A definition by Gersten and Chard (1999), states that number sense refers to, “a child’s fluidity and flexibility with numbers, the sense of what numbers mean, and an ability to perform mental mathematics and to look at the world and make comparisons” (p.20) (R. Gersten & Chard, 1999). Definitions go on further to describe the relationship between number sense and mathematics as similar to the relationship between phonics and reading. Kalchman, Moss, and Case (2001) developed a second definition describing number sense as involving fluency in estimation, flexibility in mental computation, the ability to recognize unreasonable results, the ability to transition among different representations, and using appropriate representation (Kalchman, 2001).

Despite the lack of a jointly agreed upon definitions of number sense, researchers’ have postulated several specific skills that make up the concept of number sense. These include, but are not limited to, counting, quantity discrimination, estimation, possessing a mental number line, and the ability to use multiple representations of the same number (Berch, 2005; R. Gersten, et al., 2005). Factor analytic studies indicate that counting and quantity discrimination appears to be

the two strongest predictive factors involved in number sense. These two skills serve as precursors to other number sense skills such as estimation and using multiple representations. Gersten, Clarke, and Jordan (2007) have emphasized quantity comparisons as being central to all other number sense skills (R. Gersten, Clarke, B.S., & Jordan, N.C., 2007).

Building on theoretical and operational definitions, the number sense theory assumes itself as the foundational building block of all other mathematical concepts and knowledge. Shapiro (2004) defines number sense skills as a pivotal prerequisites enabling students to facilitate basic mathematics computational knowledge (Shapiro, 2004). Also, in a paper outlining their conceptualization of number sense, Gersten and Chard (1999) highlight that number sense leads to automaticity in mathematics and is crucial to students' ability to solve basic arithmetic computations (R. Gersten & Chard, 1999).

Gersten et al. (2005) echo this notion and state that conceptual linkages associated with number sense are necessary tools for assisting students with thinking about mathematics problems and developing higher order thinking for working on mathematical problems. Interestingly, many of the skills associated with number sense are related to the hallmarks of mathematics difficulties. Students with Math Learning Disabilities (MLD) show deficits in counting skills and strategies, perceptual skills related to recognizing symbols and signs, sequencing, and fact retrieval (Association, 2000; R. Gersten, et al., 2005). Making this connection creates an even stronger case for the assessment of number sense skills and how early intervention efforts on these skills is even more important.

Based on the work of Kamii (1982, 2000) children attempt to quantify or create approximations of existing sets of objects. Kamii found that initially children apply a global strategy for quantification, relying heavily on visual perception to estimate the quantity of objects in the set. As children become more logical in their thinking, they begin to apply one-to-one

correspondence and develop relationships of quantification. Finally children use counting strategies to help quantify objects. However, for children to apply counting to the process of quantification they must understand cardinality, the concept that when they count, the last object counted represents the total (C. Kamii, 1982; C. Kamii, 2000).

Even though a growing body of research underscores the importance of examining number sense skills as part of early intervention efforts; these assessment methods vary. The following section will further explain assessment approaches and tools used to identify students with mathematics difficulties. Specifically, the section will emphasize Curriculum Based Measures (CBM) use in a formative evaluation framework to identify early mathematics skills deficits.

### **Mathematics Assessment**

Psychological and educational assessment has and still does rely on the use of norm-referenced, standardized cognitive and achievement tests to assess and diagnose Learning Disabilities (LD). Fuchs et al. (2003) explained that educators came to characterize LD as a severe discrepancy between performance on cognitive (IQ) and achievement (D. Fuchs, Mock, Morgan, & Young, 2003). This definition is consistent with current diagnostic criteria set forth in the DSM-IV-TR. In recognition most state departments of education have adopted this discrepancy principle, or the IQ-Achievement discrepancy approach, as the basis for determining LD and the subsequent provision of special education services. The primary purpose of the discrepancy approach, then, is to identify students who meet criteria for LD. This approach has been successful in that it has allowed many students to receive services. Outside of their use for determining discrepancies between cognitive functioning and academic performance, commonly used norm-referenced assessment tools are beneficial in that they provide information on students' performance and allow schools to compare large samples of their same-aged peers.

Recently, investigators and school personnel alike have advocated for alternative approaches to the discrepancy approach for identifying academic difficulties. These alternative approaches are due to growing criticism of the accuracy and efficiency of this method. For instance, one criticism is that the discrepancy approach is highly inconsistent across states (Fletcher, Coulter, Reschly, & Vaughn, 2004; D. Fuchs, et al., 2003; NJCLD, 2005). It has been found that there are inconsistencies with how discrepancy is computed, for example by either subtracting a student's standard achievement score from their total standard IQ score, or by examining the regressing of IQ on achievement. Secondly, the size of the discrepancy required to make a determination of LD is inconsistent, ranging widely from 1 to 2 standard deviations. Finally, the specific tests used to measure intelligence and academic achievement also vary. All of these problems can be identified when comparing students from state to state. A student may therefore be identified as LD in one state then travel to another and not be labeled as LD.

The NJCLD (2005) and others (e.g. D. Fuchs et al. 2003, Fletcher et al. 2004) have stated that the discrepancy approach is essentially a "wait-to-fail" model where students must demonstrate poor performance for years before their achievement scores fall significantly below their IQ scores. The discrepancy approach has shown to exclude low achieving students who may not demonstrate significant discrepancies, but are no less deserving of academic support services. This is especially true as research suggests that the performance of low achieving students and students diagnosed with an LD on the basis of and IQ-Achievement discrepancy cannot be reliably differentiated (Fletcher, et al., 1994). In other words, this identification approach may not be providing necessary support services to students until they are performing substantially behind their peers, and possibly beyond the help of intensive intervention practices. Therefore, helping these students catch up to their classmates has been made more challenging and often results in special education serving as an end point rather than a gateway to more individualized appropriate instruction (NJCLD, 2005).

Working in the current education field, where a premium is placed on early identification and intervention, the discrepancy approach for identifying LD is losing strength and other procedures that make support services available for children in a more timely fashion are being heavily considered as replacements. Changes have taken place in educational legislation and research which reflect the criticisms of more traditional assessment approaches.

One such change has been the adoption of a Response to Intervention (RTI) approach. RTI has become a vital service framework for students with learning disabilities. The most recent reauthorization IDEIA (2004) indicated that RTI may be used to assess and monitor students with learning difficulties in addition to, or in place of, former practices involving examining discrepancies between students' cognitive abilities and academic performance, as measured by standardized, norm-referenced measures (IDEIA, 2004). Complementing the revisions of IDEIA, a report from the NJCLD (2005) recommends the notion of assessment to include formative methods which can be used to screen students for academic difficulties and monitor performance across all children. This last remark fits well within the framework of a multi-tiered model of service delivery such as RTI. D. Fuchs et al. (2003) also note that many professional organizations support RTI approaches including The Division for Learning Disabilities of the Council for Exceptional Children, The International Dyslexia Association, The National Association of School Psychologists, and The National Association of State Directors of Special Education, to name a few (D. Fuchs, et al., 2003).

The most current revisions of IDEIA (2004) introduced RTI as a way to possibly reduce many of the problems associated with the IQ-Achievement discrepancy model. RTI has been proven to help more students in a timelier manner, provide high quality individualized and intensive instruction to students, and potentially to reduce special education enrollment and associated costs. RTI provides services that do not depend on IQ test performance, making it an

effective and efficient intervention and assessment tool (D. Fuchs, et al., 2003). In this way, RTI presents several advantages over the IQ-Achievement discrepancy model.

Given the necessity for screening and frequent data collection on students' progress in the curriculum, RTI uses brief, standardized measures, which are matched to the curriculum. However, as indicated earlier, many standardized, norm-referenced assessments do not fit this description. Several researchers (e.g., (Bieber & Choi, 2004; Deno, 1992; Shapiro, 2004) have pointed out that norm-referenced achievement tests are not always related to the curriculum used in particular schools. These tests do not directly relate to educational interventions, and are not a necessarily efficient way to measure short-term, individual student progress. In addition, achievement tests have many different types of items and therefore, may mask specific deficits. Therefore, while proponents of alternative assessment approaches will acknowledge that many standardized, norm-referenced achievement and cognitive tests are well designed and provide useful data; they argue that they have limited utility for progress monitoring and intervention planning (R. Gersten, et al., 2005; M. R. Shinn, & Bamonto, S. , 1998). In contrast to norm referenced tests, Curriculum Based Measurements are specifically designed for exactly these purposes.

### **Curriculum-Based Measurement**

The recent need for a more accurate and efficient mode of assessment has arose and research has formulated Curriculum Based Measurement (CBM). CBM is a form of assessment which measures academic skills with several unique characteristics that set it apart from other forms of academic assessment. CBM is brief, simple to administer, matched to curriculum and intervention and, is sensitive to short-term growth (Bieber & Choi, 2004; Shapiro, 2004). The uniqueness of CBM is in line with the President's Commission on Excellence in Special Education (2002) to incorporate formative assessment techniques that inform instructional and

intervention practices. The National Joint Committee on Learning Disabilities (NJCLD, 2005) has emphasized the importance of curriculum-based assessment and progress monitoring to effectively identify and provide services to students with learning disabilities (NJCLD, 2005). CBM can also play an important role in RTI, which stresses empirically-supported instruction, early identification, implementation of intervention with treatment validity, and progress monitoring. This is especially important since the recent re-authorization of IDEIA, 2004 which includes RTI as an alternative to the discrepancy approaches for making special education eligibility decisions.

CBM is developed as an assessment tool aligned with the classroom curriculum providing teachers with ongoing information regarding academic development and thereby guiding instructional decisions within their class (Shinn & Bamonto, 1998). This measure fulfills the guidelines published by the National Council of Teachers of Mathematics (2000) that “Assessment should become a routine part of the ongoing classroom activity rather than an interruption” (p. 23)(Mathematics, 2000b).

Assessment of students’ skills is a core component of educational practice. This is described as a process of collecting data in order to understand students’ problems and make individualized educational decisions (Salvia, Ysseldyke, & Bolt, 2001). Salvia et al. identify five types of decisions that can be made from assessment measures: (a) referral, (b) screening, (c) classification, (d) instructional planning, and (e) progress monitoring. In addition, it was noted that school personnel would benefit from using assessment data to determine the effectiveness of various educational programs and interventions (Salvia, et al., 2001).

The ability for professionals to match assessment data with the development of interventions is a critical component for school professionals. For example, Shapiro (2004) describes norm-referenced instruments as being for classification; while criterion referenced



measures create a more effective match to relative strengths and weaknesses among students (Shapiro, 2004). CBM has shown effective for making decisions about students' responsiveness to interventions, and identifying specific skills on which to intervene.

When the criticisms of the discrepancy approach are viewed in total, the need for a simplified curriculum matched assessment technique arises. As support for a RTI model increases, there becomes an apparent need for tools matched to decisions about planning interventions and useful as progress monitoring measures. Curriculum Based Assessment (CBA) is one type of assessment strategy used to smooth the development of early identification and monitoring assessments. CBA assessments fit directly within a RTI framework, and provide an efficient battery for identifying struggling students and developing specific interventions. CBA has been referred to as a direct standardized assessment of basic academic skills (Shapiro, 2004).

Different models of CBA have been developed, including criterion-based and accuracy-based models (M. R. Shinn, & Bamonto, S. , 1998). Though these approaches seem very different they are based on similar theoretical and practical characteristics. The common characteristics of the various models of CBA are that assessment practices are tied to instructional interventions, they are brief, and may can be used to monitor student progress and the effects of instruction (Bieber & Choi, 2004).

Whereas CBA is a general term, CBM refers to a specific, research-supported approach to monitoring student progress. The original intent of this research was to provide special education teachers with a tool to accurately and efficiently assess the effects of their instruction (M. R. Shinn, & Bamonto, S. , 1998). Over 40 years of research literature provides support for CBM as a reliable and valid assessment approach for evaluating elementary level academic skills (Shapiro, 2004; M. R. Shinn, 1989). In effect, results of hundreds of research studies of CBM

support this tool, which researchers once denoted as an emerging alternative, and now rate as a validated alternative to traditional assessments (L. S. Fuchs, 2004; Shapiro, 2004).

Curriculum Based Measure refers to a set of “standard simple, short duration fluency measures of reading, spelling, written expression, and mathematics computation” (p.1). CBM measures keystone skills pertinent to academic achievement. The primary testing strategies involved in CBM vary depending on the subject area. In general, school personnel conduct CBM via frequently administered grade-level skill measures, called probes, which typically range from 1 to 5 minutes in length. In mathematics, CBM generally involves the administration of 2 to 5 minute probes where students write answers to computation problems and the number of digits correct per minute serves as the measure of performance. (M. R. Shinn, & Bamonto, S. , 1998).

When taken as a whole, the results of CBM research serve as vital signs of student achievement in basic academic skills. Shinn and Bamonto describe the “big ideas” necessary in understanding the best way to use CBM data from students. The central “big idea” that has been discussed is the fact that CBM was validated for use as a dynamic indicator of basic skills (M. R. Shinn, & Bamonto, S. , 1998). This unique component of CBM allows it to be used for measuring differences among and within individuals across time. The conception that CBM is a skill indicator implies its validation as a correlate of behaviors which are analytic of overall performance across academic areas (Deno, 1992). Finally, CBM has proved to be a valid measure of specific academic skills in reading, mathematics, written expression, and spelling as evidenced by concurrent, criterion-related validity correlations with other standardized academic measures (Marston, 1989).

The principal purpose of CBM as a formative assessment tool molds well within an RTI framework, as a decision making instrument (M. R. Shinn, & Bamonto, S. , 1998). Specifically, CBM can be used to identify a problem, clarify it, and measure the students’ progress after an

intervention has been developed and implemented (L. S. Fuchs & Fuchs, 2001). CBM utilizes formative evaluation and frequent progress monitoring of student performance. Due to the fact that CBM is founded on standardized procedures, it is logistically feasible to implement and sensitive to student growth over short periods of time (M. R. Shinn, & Bamonto, S. , 1998). The use of standardized procedures ensures that change in student performance can be attributed to academic growth rather than variance in assessment procedures. CBM's concise and proficient characteristics make these assessment measures a feasible an integral part of formative assessment. Sensitivity of CBM to reliably detect changes in student growth enables school personnel to make decisions about student progress during short periods of time.

Research above has indicated an assortment of intervention approaches and curriculum which may serve to develop students' academic performance. In particular, math intervention efforts have consistently identified counting principles, arithmetic skills, and mathematics vocabulary for intervention. However, it has been found evident that early intervention on the beginning skills of mathematics is advantageous for increasing math skills among students. It has been found among school personnel that when recommendations for early identification and intervention are followed, positive outcomes can be expected for students.

To review, CBM assessment procedures represent a method that can be applied within RTI framework offering several advantages worth noting. First, CBM is simple to administer, most school personnel, not just those with specialist degrees, can effectively administer measures. Second, CBM addresses many of the criticisms of traditional assessment procedures. CBM is connected to the curriculum and instructional interventions, sensitive to small changes over time, and uses consistent procedures. These properties permit frequent analysis of students' skill mastery and progress toward short-term and year-end curricular objectives. Third, CBM's brief administration time allows for rapid documentation of student progress and quick decision making. Fourth, recent research has shown that CBM may also be used to predict student

outcomes on high-stakes testing and to measure growth in secondary and early childhood programs.

### **Early Numeracy CBM**

In addition to its utility for assessing elementary level academic skills, several authors have recently proposed CBM to be used as a tool for the identification and intervention of primary academic skills (Clarke & Shinn, 2004; Daly, Wright, Kelly, & Martens, 1997; L. S. Fuchs, 2004; Vanderheyden, et al., 2004). Until recently, CBM research among primary grade (i.e., kindergarten and first grade) students has focused on reading. Gersten et al. (2005) reviewed 20 years of CBM theory building and research finding reliable and valid screening measures of beginning reading skills; while the development of early mathematics measures “is still in its infancy.” (p. 293) (R. Gersten, et al., 2005).

Exploration of Math Curriculum Based Measurement (M-CBM) in the primary grade levels is important in helping schools to address accountability requirements, which are explicitly mandated in legislation such as NCLB (2001). This research may aid schools with early intervention efforts. As described earlier, CBM facilitates evidence based practice, is brief and simple to administer, and is a method of formative evaluation (M. R. Shinn, 1989). These properties of CBM correspond with recommendations that identification of academic difficulties should be simplified and student progress be monitored over time with the intent to make data-based decisions (IDEIA, 2004; *President's Commission on Excellence in Special Education*, 2001). More importantly, using M-CBM for assessing early math skills is in line with recommendations for the early identification of students in need of academic intervention and would potentially meet the critical need for early indicators of mathematics difficulties (Dowker, 2007).

Mathematics computation represents a narrow range of skills assessed by the National Assessment of Educational Progress (NAEP). Criterion-related validity coefficients between CBM-M and NAEP range from .38-.44 (Thurber, Shinn, & Smolkowski, 2002). Studies of criterion validity have relied on commercial achievement tests as criterion measures. Allinder, et al. (1992) and Clarke & Shinn (2004) found median validity coefficients when comparing M-CBM to the Stanford Achievement Test and Woodcock-Johnson Applied Problems ranging from .74 to .83 (Allinder, Fuchs, Fuchs, & Hamlett, 1992; Clarke & Shinn, 2004).

Tests of Early Numeracy (TENs) have been identified to be used as the content of early indicators of number sense skills. Gersten and Chard (1999) found students often informally acquire number sense before formal schooling begins. In this manner, number sense skills seem to be a natural choice of content in math assessments for primary grade children. Also, number sense is necessary for learning formal arithmetic in the early elementary grades and empirically relates to learning disabilities. It can be predicted that students with low scores on measures based on Tests of Early Numeracy would demonstrate later mathematics difficulties (R. Gersten & Chard, 1999; S. A. Griffin, Case, R., & Siegler, R. S. , 1994).

Number sense theory, TENs, and M-CBM measures provided the framework for Early Numeracy CBM (CBM-EN) measures (counting, number naming, number writing, skills associated with number line knowledge, and the ability to make judgments about quantities) were developed. The National Committee of Teaching Mathematics (NCTM) proposed that pre-students should be competent in understanding numbers, mental representation of numbers, and relationships among numbers and number systems by completion of second grade (Mathematics, 2000b).

Early numeracy CBM research has identified several measures corresponding to important number sense concepts (counting, naming and identifying numbers, making

comparisons of magnitude, using number lines, and discriminating among numbers and shapes) (Foegen, Jiban, & Deno, 2007; R. Gersten, et al., 2005; Locuniak, 2008).

CBM-EN measures are based off of number sense theory and TENs. Identified measures are Oral counting (OC) (having the student count aloud from 1-100), Number Identification (NIM) (having the student id numbers 1-20 on a grid for first grade), Missing Number (MNM) (having the student id which number is missing from a pairing 3\_\_5, and the student would give 4 as the answer), and Quantity Discrimination (QD) (having the student identify which number out of a pair of numbers is larger).

The objective of CBM-EN has been to identify brief, repeatable measures which are reliable and valid, and can be used to inform instructional decisions in schools. CBM-EN research has identified several measures that correspond to significant number sense concepts (counting, naming and identifying numbers, comparisons of magnitude, using number lines, and discriminating among numbers and shapes) (Foegen, et al., 2007; R. Gersten, et al., 2005; Locuniak, 2008). Familiarity of position and magnitude of numbers along with the ability to manipulate quantities are keystone accomplishments used to predict later math computation skills (Mathematics, 2000b).

Introductory studies have shown CBM-EN possess adequate reliability, validity, and sensitivity amongst pre-school through first grades (Chard, et al., 2005; Clarke & Shinn, 2004; Daly, et al., 1997; Locuniak, 2008; VanDerHeyden, Broussard, & Cooley, 2006; Vanderheyden, et al., 2004). VanDerHeyden et al. (2006) investigated long term predictive validity of CBM-EN concepts following students from Pre-school to First grade. These findings suggest that from pre-school to kindergarten, student performance is moderately to strongly correlate. During these years students typically make significant growth. There is also evidence supporting the

importance of preschool measures for identifying children in need of intervention during Kindergarten and even First grade (VanDerHeyden, et al., 2006).

Jordan et al. in a series of studies have found that children with a Mathematical Disability (MD), regardless of whether they are specific (MD-only) or accompanied by reading difficulties (MD/RD), perform below children with normal math achievement on timed calculation tasks (Hanich, 2001; Jordan, Hanich, & Kaplan, 2003a, 2003b). Barnes et al. (2006) also reported children suffering from MD have deficits in speed and accuracy in single-digit addition, independent of reading status (Barnes, et al., 2006).

Locuniak and Jordan (2008) identified Counting, Quantity Discrimination, Nonverbal calculation, story problems, and number combinations as primary predictors of calculation fluency amongst Kindergarten age students. Screening in kindergarten, using "at-risk" versus "not-at-risk" criteria, 84% of the children were identified who did not go on to have calculation fluency difficulties. These criteria positively identified 52% of the children who went on to later have math fact fluency difficulties in 1<sup>st</sup> and 2<sup>nd</sup> grade (Locuniak, 2008).

Jordan, Hanich, and Kaplan (2003b) identified third graders demonstrating good and poor mastery of number combinations in both addition and subtraction. Using longitudinal data, they looked at the development of numerical and cognitive competencies across second and third grades. Children with poor fact fluency and accuracy showed remarkably flat growth on timed fact-retrieval tasks. Students consistently relied on their fingers for calculation support, slowing their fluency and. In contrast, children with good fact mastery showed incremental growth in fact retrieval, along with a gradual decrease in finger counting. The transition from physical (counting-based) to mental (memory-based) representation is valuable for developing fact fluency (Geary & Hoard, 2005; R. Gersten, et al., 2005).

Development of fluency on number combinations seems to be constrained by weaknesses in accessing, comparing, and mentally manipulation number representations. Landerl, Bevan, and Butterworth (2004) define developmental dyscalculia, a clinically diagnosed severe calculation disability, as having a “highly selective” deficit in mentally representing or processing numerical information (Landerl, Bevan, & Butterworth, 2004). Development of CBM-EN skills is an integral part of building math knowledge. Current research of CBM-EN identifies measures best used as predictors for math achievement among primary elementary grade students.

Jordan et al. (2007) found that Number Sense measures accounted for 66% of the variance in predicting math achievement from Kindergarten to First grade. Quantity discrimination had the strongest correlations at each assessment time (Fall, Winter, and Spring) with a median correlation of .54 with the Woodcock Johnson III Achievement tests of calculation and fluency (Jordan, Kaplan, Locuniak, & Ramineni, 2007). Quantity discrimination was measured both in the original form (identifying the larger number given two numbers in a box) and the triangle form (identifying which number is closer to the number at the top of an equilateral triangle).

Locuniak and Jordan (2008) looked at the skill of QD, using an equilateral triangle instead of the traditional measure. Students were asked to identify which number was closer to the number at the top of the triangle. Digit span forward and backward, basic calculation fluency and vocabulary were also measured. Scores from these measures were used to determine their predictability of Second grade math calculation (Locuniak, 2008).

A two model regression determined which measures accounted for the highest predictive validity of math calculation from Kindergarten to 2<sup>nd</sup> grade. When age, reading, and general cognitive measures are accounted for, quantity discrimination is responsible for 16% of the predictive variance. The second closest predictor was 1x1 computation skills which accounted for



14% of the predictive variance. Student's demonstrated a .86 increase in calculation fluency for every 1 point increase in quantity discrimination, and a .57 increase in calculation fluency for every 1 point increase on 1x1 computation (Locuniak, 2008). Quantity discrimination predicted calculation fluency over and above general predictors.

Martinez et. al. (2009) tested the Technical Adequacy of CBM-EN in kindergarten. A total of 59 kindergarten students took part in the study. Aims-web CBM-EN measures (OC, NIM, MNM, and QD) were used (Clarke & Shinn, 2004). These measures were compared with the Stanford 10 Achievement Test (SAT-10). CBM-EN measures were collected in the fall, winter, and spring for all of the students during the schools regular benchmark periods. Predictive validity scores between the fall administration and the SAT-10 are as follows: OC was .45( $p<.01$ ), NIM was .31 ( $p<.05$ ), QD was .46 ( $p<.001$ ), and MNM was .36 ( $p<.05$ ). Results indicated that during First grade QD was the best predictor of SAT-10 scores in the fall, and in the spring was found to be the solitary predicting variable for SAT -10 scores ( $R^2=.33$ ),  $F(7,37)=4.11, p=.002$ . Students showed an average increase of .32 digits correct per week on QD from fall to spring administration. Among students, for every 1-point increase on the QD-CBM measure, SAT-10 standard scores increased an average of 2.6 points between kindergarten and 2<sup>nd</sup> grade. (Martinez, Missall, Graney, Aricak, & Clarke, 2009). Current research has indicated QD having generated the strongest evidence for conventional reliability and predictive validity among kindergarten and first grade students, over all other CBM-EN measures.

This research has provided further support for the importance of assessing quantity discrimination and its unique importance as an early screening measure. Students entering First grade differed in their ability to answer quantity discrimination questions such as, "Which number is bigger, 5 or 4?" even when student abilities of counting and simple computation have been controlled. Intervention in first grade on more complex early numeracy skills such as quantity discrimination, may allow students to quickly catch up with their peers.

Knowledge of relative position and magnitude of numbers (quantity discrimination) along with the ability to manipulate quantities through addition and subtraction are contributing kindergarten accomplishments (Mathematics, 2000b) and proven to predict later fluency. Fluency refers to the ease and accuracy with which a skill is carried out. Fluency of basic math calculations is an important tool for solving most math problems. Efficiently performing operations with multi-digit numbers (whole or rationale), positive or negative depends on fluent knowledge of number combinations. A child with weak abilities to consolidate number facts reduces their cognitive and attention resources found necessary for higher-level problem solving (Goldman & Pellegrino, 1987). Students with low fact fluency have particular challenges when being instructed in advanced mathematical reasoning.

Performing early intervention is crucial and reduces the severity of learning difficulties. Given the novelty of current research, it is important to continue the investigation of CBM-EN measures, to identify new measures which may tap into new areas of number sense not previously considered.

More-over, number sense and specifically QD during Kindergarten and 1st grade is highly correlated with and predictive of math achievement in 2<sup>nd</sup> grade. Recent research has demonstrated how number sense measures relate in particular to math fact fluency, a definitive marker for MLD in second grade and beyond. Mastery of numerical magnitudes should allow students to internalize and master basic math facts and number combinations more rapidly in early elementary grades.

### *Summary*

In summary quantity discrimination is an essential conceptual structure of number that affects many links among mathematical relationships, principles, and procedures. These links in procedural knowledge are necessary for students to build fluent and complex math skills. Fluency

will allow students to quickly develop higher order procedures. In 6 and 7 year-olds, two components of number sense are necessary (counting and quantity discrimination). These skills need to be well linked for a student to become proficient at mathematical thinking and computation.

The purpose of this research is the development of an effective early numeracy intervention, which can be used in early childhood programs by teachers to assess and increase the ongoing development of mathematical understanding and early numeracy skills. I aim to find whether intervening on the robust skill of quantity discrimination among first grade students will increase their math computation fluency and overall mathematical thinking.

Research Question #1 Which taped problems intervention will lead to the greatest learning rates amongst first graders?

Research Question #2 Which taped problems intervention will lead to the greatest increase on student's early numeracy skills?

Research Question #3 Will providing a taped problems intervention on traditional and triangle quantity discrimination, increase a child's calculation fluency?

Research Question #4 Will providing a taped problems intervention on traditional and triangle quantity discrimination increase a student's math knowledge?

## CHAPTER III

### METHODOLOGY

This chapter provides an explanation of the participant selection, sample characteristics, descriptions of the setting, assessments, research design, and data collection procedures and analysis. The current study was designed to develop an effective early numeracy intervention which can be used by teachers to assess and increase the ongoing development of early numeracy skills. I aim to find whether intervening on the robust skill of quantity discrimination among first grade students will increase their math computation fluency and overall mathematical understanding. Quantity discrimination is an essential conceptual structure of number that affects many links among mathematical relationships, principles, and procedures. The following research questions were developed to meet the purpose of this study:

Research Question #1 Which taped problems intervention will lead to the greatest learning rates amongst first graders?

Research Question #2 Which taped problems intervention will lead to the greatest increase on student's early numeracy skills?

Research Question #3 Will providing a taped problems intervention on traditional and triangle quantity discrimination, increase a child's calculation fluency?

Research Question #4 Will providing a taped problems intervention on traditional and triangle quantity discrimination increase a student's math knowledge?

### *Participant Selection*

The population for this study was first grade students from a mid-American elementary school district. The accessible sample for this study was a total of 123 first grade students in a school district in the Oklahoma City Metropolitan Area. The sample population consisted of 47% male and 53 % female, 7% Asian/Pacific Islander, 7% African American, 8% Latino, and 78% Caucasian. Approximately 40.3% of the sample population qualified for free and reduced lunch. The students in the sample population were classified as fully English proficient.

For the current study, participants were selected using convenience sampling from one elementary school within the district. All first grade students enrolled at this school were recruited to participate in the study. Forty participants were assigned to the control group, forty one to the triangle QD group, and forty two to the traditional QD group. Parent consent (Appendix A) and child assent (Appendix B) forms were given to all possible participants in the study, which included the benefits and risks of participation, and invited continued participation in the study. The forms were given to the classroom teachers to send home with the students their weekly folders. I did not include data from students whose parents returned forms indicating that they did not wish their child to participate. All students and their parents agreed to participate in the study.

### *Setting*

The school setting is an elementary school which includes pre-kindergarten through fifth grades and is located in the Oklahoma City Metropolitan Area. There were six first grade classrooms in the school, all the classrooms in were used for data collection. The average classroom size was 20 students. Data collection was completed in the each of the 6 general education classrooms. These areas were spacious, bright, and allowed for ease of access to all

participants. The intervention procedures were conducted in the 4 general education classrooms that made up the two intervention groups.

### *Research Design*

This study employed a 3x2 between groups split-plot doubly multivariate multiple analysis of variance design (DM MANOVA). DM MANOVA was used to analyze student responses on the assessments because they are not independent of one another and are considered to be correlated factors. Thus the pre/post assessments were within-subject factors and the child's group (Treatment 1, Treatment 2, and Control) were the between subject factors. Student performance was assessed before and after a 5 week taped problems intervention on the skill quantity discrimination. Student's were assessed at the beginning and end of the intervention period using the Number Knowledge Test, triangle QD assessment, traditional QD assessment, and basic addition assessment.

Students were divided into three groups averaging 40 students in each group. Convenience sampling used to determine group selection. Treatment 1 QD-triangle probe, treatment 2 QD traditional probe, and control group. Groups 0 and 1 were given a taped problems intervention in class using the intervention probes for 5 weeks to build early numeracy skills. Intervention sessions lasted 5-7 minutes each day. Student assessments and interventions were conducted by my-self and graduate students who were trained fully in the assessment and intervention procedures. Prior to beginning all research procedures, district permission and institutional review board approval (Appendix C) was obtained to conduct research.

The Number Knowledge Test was analyzed using a cell size of 8 for all three groups. This was due to the length of time required to complete this assessment (20-25 minutes). This assessment was analyzed alone using the DM-MANOVA procedure so that it could be equally compared with all other assessments across groups.

### *Experimental Assessments*

The experimental assessments consisted of the Number Knowledge Test, addition computation probe, traditional quantity discrimination probe, and triangle quantity discrimination probe.

#### *Number Knowledge Test*

The Number Knowledge Test is a normed test that assesses student's developmental age on mathematics skills. The test does not assess math language, but rather the specific math concepts. Language is taken out of the equation so that you don't overestimate students with strong verbal skills or underestimate students with weak verbal skills. The Number Knowledge Test was designed to assess the intuitive math knowledge that the average child has developed at the age-levels between 4 and 10 years old. The test assessments are normed for students between 2 and 10 years of age. This makes the Number Knowledge Test an excellent choice for beginning elementary age students.

The Number Knowledge Test is a 4-level developmental math test. This means that knowledge assessed at level 0 is generally acquired before knowledge assessed at level 1, and this knowledge is generally acquired before knowledge assessed at level 2, and level 2 before level 3. It also means that knowledge at each level of the test is a prerequisite, providing the conceptual building block for knowledge at the next level of the test. Teachers thereby are able to collect valuable information relevant to instructional planning. Identifying the developmental level each child in your classroom is presently functioning, will allow you to make informed and appropriate instructional decisions (Okamoto & Case, 1996).

### *Addition Computation Assessment*

The addition computation assessment (Appendix D) consists of single digit addition problems sums to 10. Students were asked to try each problem and move on to the next problem if they began to struggle or did not know the answer to a problem. Examiners reported performance on digits correct, taking the median of three one minute timings. An assessment sheet was placed face down in front of the students and they were told to write their name on the back of the sheet. Students were told to “Start at the top of the page and begin with the first problem and work across the page, then go to the next row. If you cannot answer a problem, mark an ‘X’ through it and go to the next one. Ready, begin”. After the three one minute assessments were over the student probes were collected and later scored for digits correct per minute.

### *Traditional Quantity Discrimination*

The traditional quantity discrimination assessment (Appendix E) required students to name which of two visually presented numbers is larger. Experimenters gave participants a grid with 40 boxes containing two random numbers, constituting a total of 40 items. At the first grade level, this assessment contains numbers ranging from 0-20. One number is always larger than the other in each pairing of numbers. If the participants stop, struggle or hesitate for more than 3 seconds, examiners encouraged them to move on and try the next one (Clarke & Shinn, 2004). Examiners reported the median score of three one minute assessments.

### *Triangle Quantity Discrimination*

The triangle quantity discrimination assessment (Appendix F) required students to identify which number at the bottom of an equilateral triangle was closest to the number at the top. Experimenters gave participants a grid with 40 boxes with a triangle in each box made up of random numbers, constituting a total of 40 items. Numbers on the triangle ranged from 0-20. One number on the bottom of the triangle was always closer to the number at the top of the triangle. If



the students stop, struggle, or hesitate for more than 3 seconds on a problem, examiners encourage them to move on and try the next one. Examiners report median scores of three one minute assessments.

#### *Examiner training.*

Examiners consisted of the primary author and six school psychology graduate students, all of whom had bachelors and /or master's degrees in the field of psychology or related field of study. All examiners, including the author, were doctoral level students in the school psychology program at Oklahoma State University. The primary investigator provided examiners with test materials, reviewed test protocols, reviewed intervention protocols, standardized instructions, and gave them opportunity to practice the procedures and ask questions. In addition CBM training was part of the masters or doctoral course work of all the examiners. This training was repeated during the research training sessions to assure procedural and scoring integrity was met by all examiners.

#### *Data Collection*

Data was collected over 25 days. On the first and last day of data collection, the primary researcher reviewed the plan for the day with the data collectors. Examiners were assigned classrooms and given materials. The data collection process began with each team member accompanying the primary researcher to a classroom for a brief introduction between the teacher and team member. With the classroom teacher present assessment procedures were reviewed then distributed.

#### *Procedures*

The primary researcher met with the principal, academic coordinator, and first grade teachers to discuss the distribution and collection of parental consent forms, data collection, and

the dissemination of participants' results. During this meeting the researcher provided each teacher with a folder containing parent consent and child assent forms. Teacher (Appendix G) and principal (Appendix H) consent forms were signed and collected. Prior to data collection, the researcher returned to the school to collect school demographics, parent consent and child assent forms, and class rosters.

The primary researcher prepared all materials. For data management purposes participant data collection and intervention folders were created. These folders were identified with student names and color coded for each teacher. Until time of testing, all folders, forms, and test protocols were stored in the primary researcher's university office in a locked container marked dissertation math study.

#### *Assessment procedures*

Students were all given the Number Knowledge Test, addition computation assessment, traditional QD assessment, and triangle QD assessment on the first and last day of the research project. An assessment sheet was placed face down in front of the student and they were told to write their name on the back of the sheet for each assessment probe. Each student was given 3 traditional QD, 3 triangle QD, and 3 sums to 10 assessments. The median score from these measures were used for student data on the pre and post assessments.

For each addition computation probe the following directions were read "start at the top of the page and begin with the first problem and work across the page, then go to the next row. If you cannot answer a problem, mark an 'X' through it and go to the next one. Ready, begin".

For each aims web QD assessment probe the following directions were read, "The paper in front of you has boxes on it. In the boxes are two numbers. When I say start, I want you to tell me the number in the box that is bigger. Start here and go across the page. If you come to a box

and you don't know which number is bigger, I'll tell you what to do. Are there any questions? Put your finger on the first one. Ready, begin."

For each triangle QD assessment probe the following directions were read, "Look at the paper in front of you. It has three numbers in the shape of a triangle. I want you to tell me the number in the bottom of the triangle that is closer to the number at the top of the triangle. If you come to a box and you don't know which number is closer, I'll tell you what to do. Are there any questions? Put your finger on the first one. Ready, start." After the assessments were over the student probes were collected and scored.

#### *Intervention Materials/Procedures*

All students in groups 1 and 2 were given folders labeled with their name and classroom, in which intervention probes were kept for the week. These probes were numbered 1-5 to correspond with each day of the week. At the beginning of each intervention session students were asked to get out their folders and remove probe (# for that day). They would place the probe face down on the desk and listen to the directions from the CD player located in the room. A master schedule was created denoting which audio track should be played each day of the week, along with which intervention probe should be used. These schedules were kept in teacher folders along with the audio CD's at the desk of the teacher in each classroom. The primary investigator and graduate students all received copies of the weekly intervention schedule.

Probes for the traditional and triangle QD taped problems interventions were made so that no two probes contained the same set of problems. No intervention probe contained the same set of problems which appeared on the pre/post assessment assessments. Audio tapes were recorded using each of the intervention probes. The problems were read then followed by the answer for each probe. Before beginning the taped problem sets the master directions were read at the beginning of each intervention session. An intervention probe was placed face down in front

of every student while sitting at their desks. The students were told to write their name on the back of their probe. Then the CD containing the intervention audio recording was played for the class.

*Master directions for taped problems intervention:*

“The following recording is going to give you some directions followed by some problems and their answers I want you to try to beat the tape to the answer for each problem. If you complete the worksheet before the tape is finished sit quietly until the tape says stop. Then raise your hand and your work sheet will be collected. Thank you and have a great day.”

The student intervention probes were collected each week and replaced with new probes for the following week after completing of the intervention each Friday.

*Integrity*

Intending to record procedural errors and provide immediate corrective feedback, the primary researcher and graduate students observed the researcher administering procedures across 70% of the intervention sessions. This was done by following a procedural integrity sheet each of the days the intervention sessions were observed. Procedural integrity collected across these sessions was 95-100% indicating administrations followed the procedures correctly.

*Inter-scorer Agreement*

The primary researcher along with an additional doctoral level student fully trained in the CBM assessment scoring procedures, independently scored the assessment data. Inter-scorer agreement for digits correct was calculated by dividing the number of agreements by the number of agreements plus disagreements and multiplying by 100. Across assessment probes, average inter-scorer agreement 93% (range 90% - 97%) between the primary researcher and additional doctoral student.

### *Chapter Summary*

In this chapter, the methodology of the current study was presented. For the current study, the primary researcher trained personnel, oversaw the data collection process, and entered all data for analyses. The current study examined the benefits of an early numeracy intervention, if one intervention would be more effective, and if intervening on quantity discrimination would increase student's math skills. To investigate this relationship, the researcher conducted a 3x2 doubly multivariate multivariate analysis of variance. These results can be described in chapter IV.

## CHAPTER IV

### RESULTS

The purpose of this research is the development of an effective early numeracy intervention which can be used by teachers to assess and increase the ongoing development of early numeracy skills. I aim to find whether intervening on the robust skill of quantity discrimination among first grade students will increase their math computation fluency and overall mathematical understanding. Quantity discrimination is an essential conceptual structure of number that affects many links among mathematical relationships, principles, and procedures.

Quantity discrimination during 1st grade is highly correlated with and predictive of math achievement in 2<sup>nd</sup> grade. Recent research has demonstrated how number sense assessments relate in particular to math fact fluency, a definitive marker for MLD in second grade and beyond. Mastery of numerical magnitudes allows students to internalize and master basic math facts and number combinations more rapidly in early elementary grades.

This chapter provides a presentation of the data to address the research questions of this intervention comparison study. The following research questions were examined to meet the purpose of this study.

Research Question #1 Which taped problems intervention will lead to the greatest learning rates amongst first graders?

Research Question #2 Which taped problems intervention will lead to the greatest increase on student's early numeracy skills?

Research Question #3 Will providing a taped problems intervention on traditional and triangle quantity discrimination, increase a child's calculation fluency?

Research Question #4 Will providing a taped problems intervention on traditional and triangle quantity discrimination increase a student's math knowledge?

The data collected during this project has been adjusted for analysis. Ceiling effects on the traditional QD assessment caused student scores to become inflated during post test assessment. Students (18 total across all 3 groups) who had reached a maximum score of 40 on the traditional pre-test assessment have been removed from the data to counter act this inflated scores and possible inaccurate results. Data analysis was conducted both with and without these 18 students. Only differences at the one thousandth of a point on significances were found. Appendix I shows graphs from both analyses, no significant interaction differences in the data were found. This indicates that these results can be considered stable. The following is a description of the data with the 18 students removed from across all 3 groups.

#### *Descriptive Statistics*

The means and standard deviations for the triangle QD, traditional QD, sums to 10, and Number Knowledge Test pre/post assessments are shown in Table 1 (Treatment ), Table 2 (Treatment 2), and Table 3 (Control). An examination of these means reveals that positive growth occurred for all assessments across each of the three groups. Growth rates were similar for all assessments so overall means were calculated for each group across all assessments and pre/post test scores were further examined.

Table 1  
*Treatment 1 Descriptive Statistics*

Assessment	<i>M</i>	<i>SD</i>	(n)
QD triangle Pre-test	13.51	3.88	40
QD triangle Post-test	18.21	6.27	40
QD traditional Pre-test	32.87	6.38	40
QD traditional Post-test	35.34	6.86	40
Sums to 10 Pre-test	15.53	6.31	40
Sums to 10 Post-test	19.68	7.47	40
NKT Pre-test	13.26	10.98	8
NKT Post-test	15.53	12.66	8
Total			40

*Source:* DM MANOVA analysis

Table 2  
*Treatment 2 Descriptive Statistics*

Assessment	<i>M</i>	<i>SD</i>	(n)
QD triangle Pre-test	12.97	4.46	32
QD triangle Post-test	15.40	5.16	32
QD traditional Pre-test	34.54	4.96	32
QD traditional Post-test	43.66	8.65	32
Sums to 10 Pre-test	17.00	12.04	32
Sums to 10 Post-test	22.09	11.03	32
NKT Pre-test	7.69	10.31	8
NKT Post-test	8.76	11.52	8
Total			32

*Source:* DM MANOVA analysis



Table 3  
*Control Descriptive Statistics*

Assessment	<i>M</i>	<i>SD</i>	(n)
QD triangle Pre-test	15.17	2.85	33
QD triangle Post-test	15.17	4.16	33
QD traditional Pre-test	33.40	7.44	33
QD traditional Post-test	36.97	7.13	33
Sums to 10 Pre-test	14.85	6.63	33
Sums to 10 Post-test	19.52	8.13	33
NKT Pre-test	8.32	10.70	8
NKT Post-test	9.40	11.91	8
Total			33

*Source:* DM MANOVA analysis

#### *DM MANOVA*

In order to examine the intervention differences among children participating in the taped problems groups, mean scores on all 4 assessments for each student were calculated and used as dependent variables. This study employed a 3x2 between groups split-plot doubly multivariate multiple analysis of variance design (DM MANOVA). DM MANOVA was used to analyze student responses on the assessments because the assessments are not independent of one another and are considered to be correlated factors. Thus the pre/post assessments were within-subject factors and the child's group (Treatment 1, Treatment 2, and Control) were the between subject factors.

The DM MANOVA revealed a significant group by time interaction for the triangle QD, traditional QD and sums to 10 assessments, Wilk's lambda = .723,  $F(5.869) = 6.00$ ,  $p = .000$ ,  $\eta^2 = .150$ . The power level for this analysis was .998. Indicating that the analysis is highly sensitive

and the chance of a type II error is low. A separate DM MANOVA was run for the Number Knowledge Test. This was done due to the limited sample cell size available for this assessment (n=8). No significant interaction was found on the Number Knowledge Test, Wilk's lambda = .957,  $F(1.932) = 2.0$ ,  $p = .151$ ,  $\eta^2 = .043$ . The power level for this analysis was .440. Indicating that the analysis has moderate strength and is sensitive, having only a moderate chance of type II error. These results can be identified in Table 4.

#### *DM MANOVA Results*

Table 4  
*Group x Time interaction*

Assessment	Sig.	<i>F</i>	df	( $\eta p^2$ )
DM MANOVA F-test	.000***	5.869	6.0	.150
NKT DM MANOVA F-test	.151	1.932	2.0	.043

\* $p < .05$

\*\* $p < .01$

\*\*\* $p < .001$

Follow-up analysis and univariate tests were then conducted to identify groups that yielded differences among the assessments. Significant group differences were found on the triangle QD assessment  $F(10.039) = 2.0$ ,  $p = .000$ ,  $\eta^2 = .164$  and the traditional QD assessment  $F(7.418) = 2.0$ ,  $p = .001$ ,  $\eta^2 = .127$ . The sums to 10 assessment  $F(.703) = 2.0$ ,  $p = .591$ ,  $\eta^2 = .004$  and the Number Knowledge Test  $F(2.712) = 2.0$ ,  $p = .072$ ,  $\eta^2 = .059$  were found to have non-significant group interactions. These results are reported in Table 5.

Table 5

*Group x Assessment interaction*

Assessment	Sig.	<i>F</i>	df	( $\eta^2$ )
Triangle QD	.000***	10.039	2.0	.164
Traditional QD	.001***	7.418	2.0	.127
Sums to 10	.814	.206	2.0	.004
NKT	.072	2.712	2.0	.059

\* $p < .05$ \*\* $p < .01$ \*\*\* $p < .001$ 

Follow up discriminate analysis and group contrast results identified the following significant group comparisons across assessments. Significant differences were found between groups on pre-test measures. Pre-test measures across groups identified the following significant differences. Treatment 2 was significant when compared to Control  $F(.167) = 2.0$ ,  $p = .001$ ,  $\eta^2 = .003$  on the traditional assessment. All other groups were found to be non-significant on pre-test assessments. This indicates that all groups were at the same academic level prior to the implementation of the traditional and triangle QD interventions. These results can be identified in Figure 1 (traditional QD assessment), Figure 2 (triangle QD assessment), Figure 3 (sums to 10 assessment), Figure 4 (Number Knowledge Test), Table 6 and Table 7.

Post-test measures across groups identified the following significant differences. Treatment 2 performed significantly better than treatment 1 and the control group on the traditional QD assessment  $F(6.630) = 2.0$ ,  $p = .002$ ,  $\eta^2 = .115$ , Treatment 1 performed significantly better than treatment 2 or the control on the triangle QD assessment  $F(6.812) = 2.0$ ,  $p = .002$ ,  $\eta^2 = .118$ . Groups showed no significant differences when compared on the sums to 10 assessment  $F(.606) = 2.0$ ,  $p = .548$ ,  $\eta^2 = .012$ . Treatment 1 on the Number Knowledge Test though approaching significance was found to be non significant compared to the other groups  $F(2.712)$

= 2.0,  $p = .072$ ,  $\eta^2 = .059$ . These results can be identified in Figures 1 (traditional QD assessment), 2 (triangle QD assessment), 3 (sums to 10 assessment), and 4 (Number Knowledge Test), and Table 7.

Figure 1  
*Traditional QD Assessment*

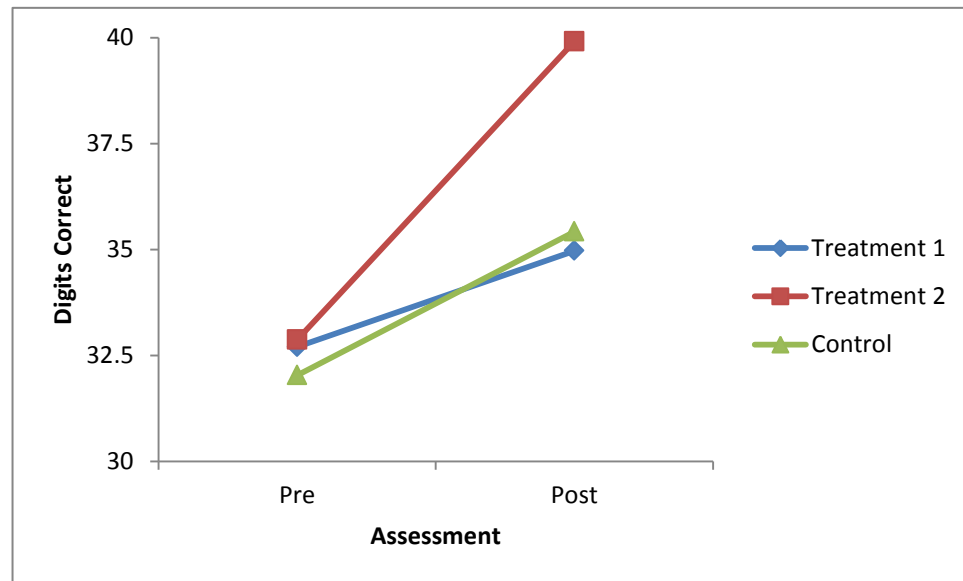


Figure 2  
*Triangle QD Assessment*

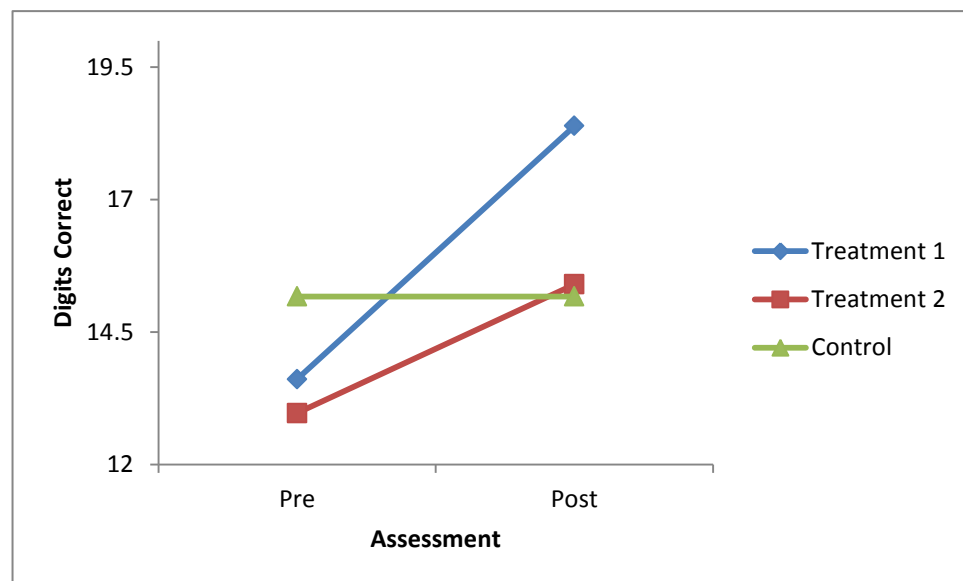


Figure 3  
*Sums to 10 Assessment*

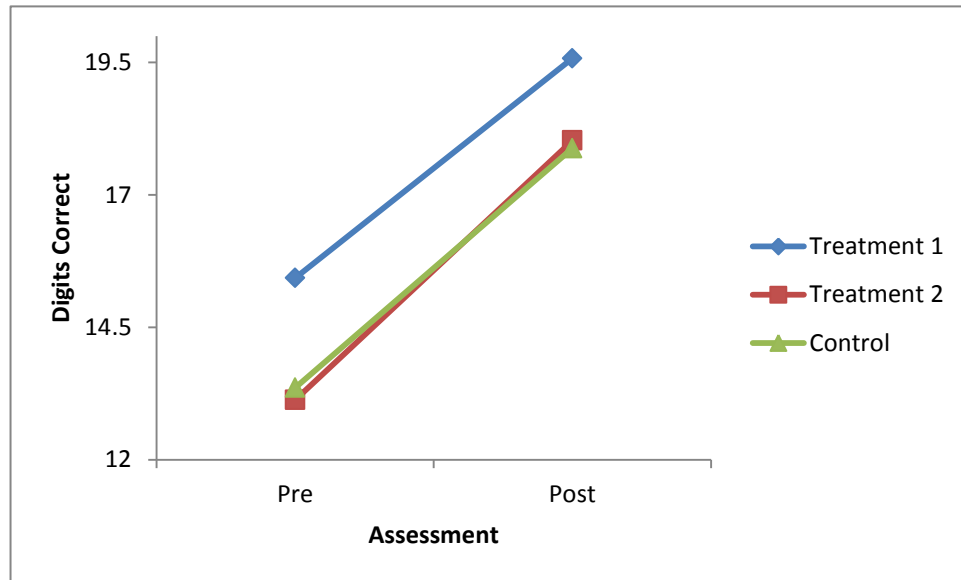


Figure 4  
*The Number Knowledge Test*

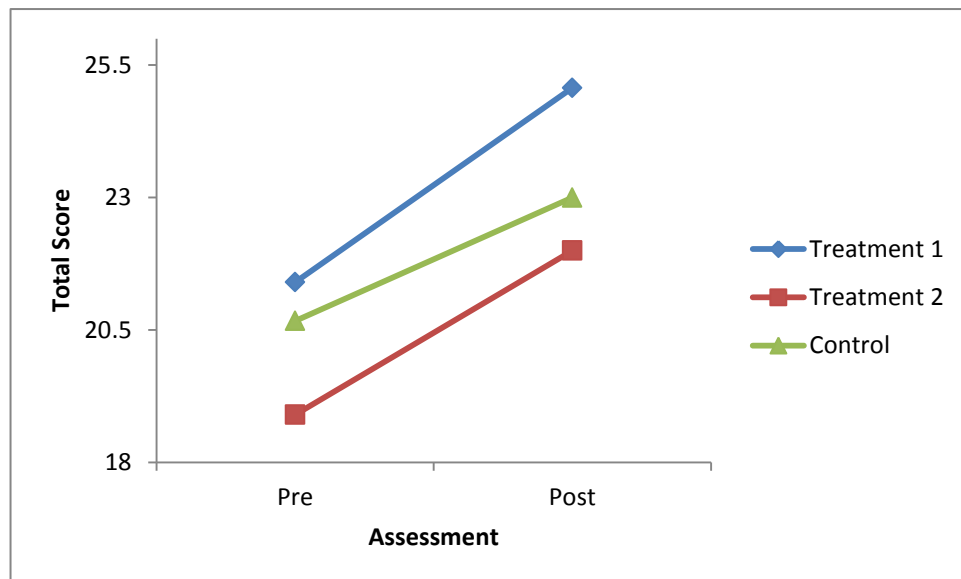


Table 6  
*Pre-test group interactions*

Assessment	Treatment 1 v. Treatment 2	<i>Treatment 1 v. Control</i>	Treatment 2 v. Control
Triangle QD	.073	.084	.001***
Traditional QD	.907	.651	.589
Sums to 10	.144	.186	.884
NKT	.066	.056	.947

$*p < .05$   
 $**p < .01$   
 $***p < .001$

Table 7  
*Post-test group interactions*

Assessment	Treatment 1 v. Treatment 2	<i>Treatment 1 v. Control</i>	Treatment 2 v. Control
Triangle QD	.001***	.005**	.625
Traditional QD	.001***	.757	.004**
Sums to 10	.378	.329	.934
NKT	.034*	.054	.844

$*p < .05$   
 $**p < .01$   
 $***p < .001$

As indicated by the above results significant group differences were observed on pre and post assessment measures. As indicated by Table 6 and Figure 2, only Treatment 2 ( $p=.001$ ) on the traditional QD assessment showed a significant pre-test difference when compared to Control.

As indicated by Figure 1 only Treatment 2 showed significant differences on post test scores when compared to treatment 2 ( $p=.001$ ) and the control ( $p=.004$ ). As indicated by Figure 2 only treatment 1 showed significant differences on post test scores when compared to treatment 2 ( $p=.001$ ) and the control ( $p=.005$ ). As indicated by Figure 3 no groups showed any significant

pre/post assessment differences. As indicated by Figure 4 only treatment 1 showed significant differences on post test scores when compared to treatment 2 (.034). Though Group differences between treatment 1 and the control group ( $p = .054$ ) were approaching significance, no significant findings were indicated.

Finally, results indicated significant group by assessment differences. Treatment 2 (Vs. Treatment 1  $p = .001$  and Vs Control  $p = .004$ ) accounted for the greatest increase in student performance on the traditional QD measure. The magnitude of this difference was moderate  $\eta^2 = .127$ . Treatment 1 (Vs. Treatment 2  $p = .001$  and Vs Control  $p = .005$ ) accounted for the greatest increase in student performance on the triangle QD assessment. The magnitude of this difference was moderate  $\eta^2 = .164$ . Treatment 1 (Vs. Treatment 2  $p = .034$  and Vs Control  $p = .054$ ) accounted for greater increases on the Number Knowledge Test, indicating it as a more effective intervention. The magnitude of this difference was low  $\eta^2 = .059$ . Specifically this indicates the triangle QD intervention as a more effective choice for increasing student's math knowledge. This growth can be seen in figures 4. The traditional QD intervention was most effective at increasing the traditional QD skill and was found to be least effective on the Number Knowledge Test and triangle QD measure.

### *Summary*

In summary, this chapter presented the results of data analyses to address the research questions of which intervention would be most effective at increasing CBM-EN skills and math knowledge. Results revealed significant growth for all groups across assessments when controlling for time alone. However, only significant interactions were found between group and time on the triangle and traditional QD assessments. Further discriminate analysis revealed significant group differences on the traditional QD, triangle QD assessments, and the Number Knowledge Test. Indicating that intervening on the specific skill of QD increases the individual scores significantly, and intervening on triangle QD increases students individual skill and

general math knowledge. As indicated by results regarding the sums to 10 measure, regardless of receiving an intervention student's show significant growth in short periods of time on basic computation facts.

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## CHAPTER V

### DISCUSSION/CONCLUSION

Given the existing state of mathematics in the United States and current recommendations for prevention of academic failure, this study helps advance the research in the area of early math intervention. Typically students are not assessed for learning disabilities until 9 years of age (Shaywitz, 1998). However research has supported the need for screening of kindergarten students for math weaknesses to ensure early identification and appropriate intervention. One purpose of this study was to develop an intervention that was efficient and effective at increasing early numeracy skills. Chapter V provides interpretation, discussion, and implications of this study.

#### *Discussion*

The current study demonstrates that a taped problem intervention is an effective tool for increasing the early numeracy skill of QD. Currently in the literature there is no known intervention research on QD or any early numeracy skills. Since QD was the most robust predictor of first grade math fact fluency it became an ideal choice for this study. To intervene daily on a class of 20 students required 7 minutes of instructional time each day. This became an acceptable form of intervention by the classroom teachers. This form of intervention can be adapted to a variety of math skills and ran by individual students at a computer or part of a whole class intervention as was used in this study.

Students were assessed pre-post of the 5 week intervention period. Assessment measures included traditional QD, triangle QD measures, sums to 10 assessment, and the Number Knowledge Test. All assessments were given in group format except for the Number Knowledge Test which was an individual math knowledge test. A team of 5 graduate students and the primary investigator collected and scored all the assessment data. Data from this study was analyzed using a doubly repeating multivariate analysis of variance.

Results from the DM-MANOVA and discriminate analyses revealed that both interventions were effective at increasing the QD skills for which they were designed. Both moderate and small effects were found when the treatment by assessment interaction was further analyzed. This indicates that treatment 2 accounts for 12.7% ( $\eta^2=.127$ ) of the between group variance on the traditional QD assessment. Treatment 1 accounted for 16.4% ( $\eta^2=.164$ ) and 5.9% ( $\eta^2=.059$ ) of the between group variance on the triangle QD assessment and Number Knowledge Test respectively. The low effect size on the Number Knowledge Test can be indicative of the mirrored change in trend across all groups on this assessment.

The univariate analysis of groups across assessments indicated that although both treatments 1 and 2 significantly increased their individual assessments only treatment 1 showed significant increases the Number Knowledge Test. This indicates that treatment 1 may have a greater impact on students over all math knowledge when compared to treatment 2 and the control group. However further examination of Figure 4 shows similar rates of growth between all groups, indicating that although treatment 1 scores are significantly better, overall growth is equal across all groups.

### *Research Question 1*

Which taped problems intervention will lead to the greatest learning rates amongst first graders?

Research question 1 deals with learning rates between the two treatment groups and the control to determine which intervention best improved student performance over the 5 week intervention period. When compared on the sums to 10 measure and the Number Knowledge Test both treatment groups and the control groups showed similar learning rates as identified by the trends in Figures 3 and 4. Treatment 1 and treatment 2 demonstrated higher learning rates on the assessments of traditional QD and triangle QD as indicated by Figure 1 and Figure 2. This indicates that the treatments were effective at increasing learning rates for only the respective assessments which they were designed for.

### *Research Question 2*

Which taped problems intervention will lead to the greatest increase on student's early numeracy skills?

Research question 2 focused on which treatment condition would increase early numeracy skills the most. The two interventions focused on individual early numeracy skills of traditional quantity discrimination and triangle quantity discrimination. Data analysis revealed that treatment 1 performed best on the triangle QD measure and treatment 2 performed the best on the traditional QD measure. This indicates that the interventions were most effective at increasing the skill for which they intervened upon. Treatment 2 performed better than the control group on the triangle assessment; however these changes in scores were not significant. Generalization across skills was not identified during this study inferring that both measures may be uniquely separate from one another.

### *Research Question 3*

Will providing a taped problems intervention on traditional and triangle quantity discrimination, increase student calculation fluency?

Research question 3 focused primarily on the sums to 10 assessment which measured student's calculation fluency during a 1 minute timing. All participants received 3 assessment probes and the median score was used as the pre-post score for each student. According to the analysis both treatment groups and the control group performed equally well at increasing student performance on the sums to 10 assessment. This indicates that the QD taped problems intervention was unsuccessful at increasing math fluency amongst first grade students. These results can be identified in Figure 3.

#### *Research Question 4*

Will providing a taped problems intervention on traditional and triangle quantity discrimination increase a student's math knowledge?

The purpose of research question 4 was determining which treatment would increase student's overall math knowledge. Student math knowledge was assessed using the Number Knowledge Test. This test is a leveled developmental norm referenced test to assess primary grade students beginning mathematical knowledge. As indicated in Figure 4 both treatment groups and the control group equally increased student scores on this assessment. Though as shown in Table 7 treatment 1 was significantly better than treatment 2 and the control group on post test scores.

A cursory look at Figure 4 indicates that differences exist between treatment 1 compared to treatment 2 and the control on the Number Knowledge Test. The relationship between treatment 1 and treatment 2 was found to be significant ( $p=.034$ ). The relationship between treatment 1 and control, was found to be approaching significance ( $p=.054$ ). This data identifies treatment 1 as more effective than treatment 2 on increasing student's general math knowledge.

Moreover, the current study provides support for the skill of quantity discrimination as a viable assessment measures as indicated by previous research (Jordan, Kaplan, Locuniak, &

Ramineni, 2007a), although intervening on the skill of QD may not generalize to other tests of math ability. Quantity discrimination is the most robust predictor of all early numeracy skills (Locuniak, 2008) and it would seem practical that intervening on this skill would increase over all math skills. This was not found in this research study, however future research as outlined below may provide a more beneficial effect.

### *Practical Implications*

The primary focus of this study was to increase student math performance by intervening on the skill of quantity discrimination, which has been proven to be the strongest predictor of math performance among first grade students (Jordan, Kaplan, Locuniak, & Ramineni, 2007b; Locuniak, 2008). The study also focused on which intervention would be more effective at increasing student's math performance. Results indicated that treatment 1 was effective at increasing triangle QD scores and treatment 2 was effective at increasing traditional QD scores.

Currently student growth on traditional quantity discrimination CBM-EN from winter to spring benchmarks is 9.3 digits or .36 digits per week over a 26 week period (Clarke, 2002). The current study has shown that intervening on the traditional QD increases student performance 7.04 digits in 5 weeks accounting for a total of 150 instructional minutes. Current research indicates typical student growth to be 1.8 digits during a 5 week period without intervention. Tape problems are an effective and efficient tool for increasing early numeracy skills. However, intervening on these individual skills seems limited to only the specific skill which students are being trained on. This study has provided evidence that implementing a taped problems intervention is beneficial for increasing individual student skills. Intervening on the specific skill of QD, however does not seem to generalize to higher order math procedures.

This research begs the question as to whether the current CBM-EN measures are as effective as indicated by past research in predicting student math performance from Kindergarten

to 2<sup>nd</sup> grade (Locuniak, 2008). Intervention of these skills would in theory increase student math performance, although as shown by this study only limited gains were obtained, none of which were significant. Building mathematical knowledge and procedures is a multifaceted process which research is just on the verge of understanding. Research in the area of mathematics needs to continue to expand upon the current findings. Working to develop the most effective assessment measures and procedures for teaching students the skills required to become proficient should be the main focus of this research.

### *Study Limitations*

Due to the length of administration of the Number Knowledge Test a smaller sample size was taken to account for overall assessment time. The lower power level of this assessment may have limited the between group differences on this measure. As well using two probes for post-test assessment and one for pre-test assessment may have caused the data to be inflated for the traditional QD assessment measure. Due to student performance ceiling out on the pre-test assessment, the post-test assessment scores could have indicated greater growth than what actually existed. Removal of the 18 students from the study to correct for the possibly inflated traditional QD scores decreased the overall power of the study and may have lead to an increased chance of type II error. Although this removal of students did not significantly affect the statistical outcome of the study as identified by appendix I, it decreased the sensitivity of finding effects amongst groups. This possibly masked finding a significant interaction effect when on truly existed.

The use of convenience sampling and not random sampling for the participant selection could have led to decreased internal validity of the study. This sampling procedure did not allow for the highest control of confounding environmental variables due to teaching style and other classroom variables. This could have lead to high and low performing students remaining

together as a group. This may have also allowed some students access to prior procedural knowledge while remaining limited to others.

Due to the area in which this sample of students was taken over all school performance was higher than the average performing area schools. This can be identified by looking at control group scores showing positive growth almost equal to treatment groups on certain assessments (figure 3 and figure 4). This may have caused depressed growth on assessment measures due to increased student pre-test scores and overall prior knowledge. Students in future studies should be sampled from the spring of Kindergarten or the fall of First grade to limit the amount of prior knowledge amongst the participants.

Student growth may have been limited due to the time of year the intervention and assessments were performed. Students may have already had prior computational procedural knowledge limiting the effectiveness of the interventions used. The difficulty of the sums to 10 math facts may have limited the studies ability to see significant differences in student performance. This may have been due to the students having already learned addition computation procedures. Measuring pre and post scores with a sums to 18 assessment instead of a sums to 10 assessment may allow for greater spread of student scores. Specifically when sampling from the spring of First grade or the fall of Second grade.

Progress monitoring data was not collected during this study. Collecting weekly or daily student data prior to the implementation of the intervention would have allowed for the tracking of student performance. This data may have allowed the researcher to make changes to the intervention to help improve the effectiveness across groups.

### *Future Research*

The basic skills identified in reading (i.e. letter names, letter sounds, nonsense words, sight words ..... lastly reading connected text) have been developed into effective interventions currently used in special education and regular education classrooms. Students have been found

to develop mathematical concepts in the same sequential manner (counting, identifying quantity, seriation, etc...). Early grades teach students to identify quantity, count, and understanding proper sequence of numbers before learning addition and subtraction skills. Further research needs to be conducted to better understand our development of math skills and identify which skills are the most important. This research is paramount in our development of effective math interventions to provide the greatest benefit to struggling students.

Future research projects should include random sampling of participants to limit confounds as best as possible. Recommendations to replicate the study with a larger sample size of the Number Knowledge Test might be justified. This would increase power and allow for better identification of significant variance among groups. Future studies should look into testing student's abilities on sums to 18 as well as sums to 10 math facts. Research may benefit from identifying other possible early numeracy measures and comparing these against the current standards. These new measures may be identified by breaking down students procedural knowledge related to math fact fluency.

Comparing two or more types of interventions on early numeracy skills may provide means of identifying an effective intervention. This study was limited by only testing one form of intervention were others (flash cards, cover copy compare, explicit timing) may be equally if not more effective at improving students over all math performance when intervening solely on early numeracy skills. These comparisons would enable us to identify effective procedures.

Additional intervention research on early numeracy skills should be conducted in the spring of Kindergarten or fall of First grade. This will allow for more accurate assessment measurement and identifying a population amongst which this intervention would be most effective. First grade students reach a ceiling on the QD measures in the spring of first grade and often have knowledge of math computation procedures, which limits their growth on this



measure. Students who are just beginning First grade or ending Kindergarten may show greater growth over the intervention period. This would allow for more sensitive assessments.

Collecting data amongst learning disabled students and those identified as having math disabilities in primary elementary grades should be considered for future research. Up to 50% of students classified as learning disabled have mathematics related items on their Individual Education Plan (IEP) (Kavale & Reese, 1992). These students are the most eligible for later developing severe difficulties in mathematics. Proper correction of early math deficits is crucial for later developing proper mathematical procedures. As indicated by prior research increased math fluency allows for the availability of expanded short memory and thus increased ability to learn more advanced mathematical knowledge and skills (Geary, 2004).

### *Conclusion*

Without accurate assessment measures to identify struggling students and effective interventions to remediate these skill deficits our student's performance will only continue to fall further behind. This study furthers the existing body of early numeracy and intervention research by providing the beginning evidence of an integrally sound intervention tool for early numeracy measures. The results were promising; however, additional research is necessary to refine the population for which these interventions would be most effective.

This study has provided an intervention that fits within the standards set in place by NCLB act and the President's Commission of Excellence in Special Education (Congress, 2002; *President's Commission on Excellence in Special Education*, 2001). The current educational reforms to apply a tiered system in our schools to provide services to students based on academic need would benefit from the development of interventions such as the one proposed in this study. Early intervention leads to prevention of future difficulties in mathematics, this study and the proposed future research will contribute to this resolution.

In summary this chapter has provided an overview of the results of this study as well as the implications it has on future research and practice in the field of early math intervention. This research has provided a starting point from which other projects can be developed and the area of math can begin to identify more effective interventions, skills on which to intervene, and the critical time frames during a student's academic career to provide these interventions.

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## APPENDICES

### Appendix A

#### Parent Permission Form

**Research study:** Impact of Taped Problem interventions for early numeracy skills (Quantity Discrimination) and overall math knowledge.

**Investigators:** Paul Hansmann M.S., Brian Poncy, Ph.D.

**Purpose:** The purpose of this research study is to aid in the teaching of early math skills. I am working to develop a procedure that can be used in school by teachers to test and increase students early math skills. The skill of focus is identifying number size (identifying the bigger of two numbers). The purpose of this research study is to find whether intervening, on the ability of identifying number size among first grade students, will increase their math fact speed and overall math understanding.

**Procedures:** Students in this research study will be randomly assigned by class to 1 of 3 groups, groups 1 and 2 are described below. Group 3 is a control group and will not receive any teaching procedures only the assessments given before and after the teaching procedures are given to groups 1 and 2. Once the groups are established, children in groups 1 and 2 will be given one of two taped-problem procedures. The taped-problem procedures use a tape recorder to play audio recordings, which read a problem, gives a short time delay, then reads the answer. The study compares two types of procedures. The first procedure is a simple number size task, where the student chooses the larger of two numbers. For example the simple number size tape will say “which number is bigger [12 or 7]”, provides a time delay, and then reads the answer “12”. The second is a complex number size task where the student chooses the closer of two numbers at the bottom of a triangle to the number at the top, or no intervention and will be used as a comparison group.

11

16/10

The complex number size task tape will ask, “Which number on the bottom is closer to the number at the top”, provides a time delay, and then reads the answer, for example “10”.

Comparing these two procedures will determine which one provides the best learning outcome for students. The procedures will take place in your child’s classroom and last 5 weeks

with one 5-minute session taking place 5 days a week. Only children whom have had permission returned will have their data used in the study, those children from whom we have not received permission will not have their data used in this research study.

Your child will be given assessments to measure their math skills before and after the taped problems procedures are given in their classroom. This will determine the effectiveness of each procedure. The first measure will be an addition worksheet maximum answer of 10. Your child will be given one minute to complete as many problems as he/she can during the one minute timing. The second measure will be a worksheet with addition and subtraction problems and be given 3 minutes to complete as many problems as they can. This worksheet will range from simple ( $1+1=2$  and  $3-2=1$ ) problems to the most difficult being ( $13+7=20$  and  $20-9=11$ ). These two worksheets will allow us to see how fast your child can complete math problems of varying difficulty. The third is a Number Knowledge measure which has a series of questions asking your child to compute addition and subtraction problems, identifying which number is larger, and answering word problems. This will allow us to determine your child's overall math skill. Your child will also be given two worksheets made up of each type of problem from the teaching procedures to show their growth before and after the classroom procedures are given.

By signing, you are giving permission for your child to participate in this research study as well as permission to have their data available for future publication after the study is over. Your student's identity will be kept confidential at all times during the research study through the use of an ID number, which will be given to your child at the beginning of the research study. If you do not provide permission your student's data will not be used for the research study. However all students will receive the class teaching procedure.

**Risks of Participation:** There are few to no risks of participation in this research study, as the target behavior (computation of basic math facts) and procedures are similar to those used in the general education setting. The student's personal information will remain confidential. Data that is collected from individual students will be averaged with other student data to prevent individual scores from being seen. Upon request the teacher and or parent(s) of the student can have access to the research study data. Student names will not be used at anytime during this research study. Only the ID numbers we provide after collecting student assent forms will be used to identify students.

In regard to the principal's, teacher's, and parent's access to student data: The principal and teacher will be given information in the form of a graph of the aggregated performance of the group and a table with the means of student performance in digits correct per minute data from the assessment phases. Parents who request information regarding their child will also receive information concerning his/her math performance. Once student information is given to the principal, teacher, and parents, the identifiers will be removed from the database and student names will be replace by ID numbers. Identifiers will remain with the data approximately 2 months after completion of the data collection.

**Benefits:** The information your child provides will assist us in better developing more efficient

and effective procedures for teaching early math skills to public school students. Similar uses of these procedures have been proven to work to increase math fluency and accuracy in students, and will likely benefit the students who participate in the research study.

**Confidentiality:** Your child's identity will be linked with information collected in this research study through the use of research ID numbers. Students will be given ID numbers and data will be stored under the student's ID number in the principal investigators office on compact discs in a locked cabinet at Oklahoma State University, or in password-protected electronic files on the principal investigator's university computer. Only the principal investigator and graduate student assistants will have access to the data. The information obtained in this research study will be reported only in aggregated form and may be published in scientific journals or presented at scientific meetings. The Oklahoma State University Institutional Review Board has the authority to inspect consent records and data files to assure compliance with approved procedures.

**Contacts:** You may ask questions regarding this research and have these questions answered before agreeing to participate in the research study. You may also ask questions during the research study. You may call the primary investigator Paul Hansmann M.S., (405) 744-4802, or his advisor Dr. Brian Poncy, (405) 744-4808 at any time to discuss this research. If you have any questions about the research and your rights as a research volunteer, you may contact Dr. Shelia Kennison, IRB Chair, 219 Cordell North, (405) 744-3377 or [irb@okstate.edu](mailto:irb@okstate.edu).

**Participants' Rights:** You are free to decide whether or not your child will participate in this research study or to withdraw their participation at any time without reprisal or penalty.

**Please check one box below and return back to your child's teacher in the enclosed envelope.** Thank you.

I have read and fully understand this information.

☐ **I DO**

☐ **I DO NOT**

**Agree to allow my child to participate in this research study.**

\_\_\_\_\_  
Your Child's Name (please print)

\_\_\_\_\_  
Parent's or Guardian's Signature

\_\_\_\_\_  
Date

Paul Hansmann, M.S.

Graduate Student OSU

Primary Investigator

School Psychology

Dr. Brian Poncy Ph.D.

Associate Prof. OSU

Advisor of Primary Investigator

School Psychology

Appendix B

**Informed Assent Form Child**

Dear Student,

You are going to be asked to work on some math problems. Some of the problems may be easy and some may be hard. I want you to try your very best. You will be asked to complete a daily worksheet followed by you listening to a tape recorded question and answer for each problem.

Please know that you do not have to do this. If you do not want to take part you will be given time to do school work. You may stop working on the math worksheet at any time.

Even though you will put your name on this form you will be given an ID number for the study so no-one will know your real name. Doing these math worksheets will not change your math grade in any way. If you have any questions about the form or what we are doing, please ask us.

Thank you for your help.

Sincerely,

Paul Hansmann, M.S.  
Graduate Student Oklahoma State University

Dr. Brian Poncy, Ph.D.  
Associate Professor Oklahoma State University

I have read this form and agree to help with your project.

\_\_\_\_\_  
(your name)

\_\_\_\_\_  
(your signature)

\_\_\_\_\_  
(date)

APPENDIX C

**HANDWRITTEN FORMS WILL NOT BE ACCEPTED**

**APPLICATION MUST BE SINGLE SIDED**

<p><b>APPLICATION FOR REVIEW OF HUMAN SUBJECTS RESEARCH</b> SUBMITTED TO THE OKLAHOMA STATE UNIVERSITY INSTITUTIONAL REVIEW BOARD Pursuant to 45 CFR 46</p>	<p>_____</p> <p>IRB Number</p> <p>FOR OFFICE USE ONLY</p>
<p>Title of Project: <b>Quantity Discrimination Intervention</b></p>	
<p>Is the Project externally funded? <input type="checkbox"/> Yes   X No   If yes, complete the following: <input type="checkbox"/> Private   <input type="checkbox"/> State   <input type="checkbox"/> Federal</p> <p>Agency:              Grant No:              OSU Routing No:</p>	
<p>Type of Review Requested:   <u>Exempt</u>   X <u>Expedited</u>   <input type="checkbox"/> <u>Full Board</u></p>	
<p><b>Principal Investigator(s):</b> <i>I acknowledge that this represents an accurate and complete description of my research. If there are additional PIs, provide information on a separate sheet.</i></p>	

Paul Hansmann		
<b>Name of Primary PI</b> (typed)	Signature of PI	Date
SAHEP- School Psychology	College of Education	
Department	College	
420 Willard Hall, Stillwater, OK 74074	405-744-4802	paulrh@okstate.edu
PI's Address (Street, City, State, Zip)	Phone	E-Mail
<a href="#">Required IRB Training Complete:</a> X Yes <input type="checkbox"/> No (Training must be completed before application can be reviewed)		
<b>Name of Co-PI</b> (typed)	Signature of Co-PI	Date
Department	College	
PI's Address	Phone	E-Mail
<a href="#">Required IRB Training Complete:</a> Yes <input type="checkbox"/> No (Training must be completed before application can be reviewed)		
<b>Adviser (complete if PI is a student):</b> <i>I agree to provide the proper surveillance of this project to ensure that the rights and welfare of the human subjects are properly protected.</i>		
Brian C. Poncy, PhD		
<b>Adviser's Name</b> (typed)	Signature of Adviser	Date
SAHEP School Psychology	College of Education	
Department	College	
420 Willard Hall, Stillwater, OK 74074	405-744-4808	brian.poncy@okstate.edu
Adviser's Address	Phone	E-Mail

[Required IRB Training Complete:](#)

X Yes

☐

No

(Training must be completed before application can be reviewed)

NOTE: If sufficient space is not provided below for a complete answer in sufficient detail for the reviewer to fully understand what is being proposed, please use additional pages as necessary.

1. Describe the purpose and the research problem in the proposed study. *Your response in this section will enable the reviewers to determine whether the project meets the criteria of research with human participants and also the extent to which the research may produce new generalizable knowledge that may benefit the participants and/or society.*

The data from this intervention will be used in poster presentations at national conferences and in a future publication in a research journal. This data will be used to help increase the knowledge base in the area of early mathematics.

2. (a) Describe the subjects of this study:

Describe the sampling population: The participants in the intervention group included six students in the Stillwater School District. Students were from a 1st grade elementary education classroom in a Stillwater elementary School. It is these 6 students that will participate in the current study.

- 1) Describe the subject selection methodology (i.e. random, snowball, etc.): Students on the basis that they received a group intervention to remediate their low early numeracy skills. No participants will be recruited other than those that already participated in the intervention.

Describe the procedures to be used to recruit subjects. Include copies of scripts, flyers, advertisements, posters or letters to be used. **If recruitment procedures will require access to OSU System email addresses you will need to include Appendix A of this application.**<sup>7</sup>

Students at a Stillwater Public School were selected to be part of a group intervention to remediate their early numeracy skills. Parent consent for the intervention was obtained as part of the school student assistance team. In the current study, parent permission will be obtained to allow for the use of this data as part of a research article (Appendix A).

Only children who have parent consent will have their data used in this research project. Parental consent forms will be sent home in the students weekly folders to their parents to read and sign and returned in the folders.

- 2) Describe the calendar time frame for gathering the data using human subjects: One year upon IRB approval.

Describe any follow-up procedures planned: No follow-up procedures are planned for this study.

- (b) Are any of the subjects under 18 years of age? X Yes ☐ No

*If Yes, you must comply with special regulations for using children as subjects. Please refer to IRB Guide.*

This project does not involve greater than minimal risk as The purpose of the study is simply to evaluate the effectiveness of a previously implemented intervention.

3. Provide a detailed description of any methods, procedures, interventions, or manipulations of human subjects or their environments and/or a detailed description of any existing datasets to be accessed for information. Please indicate the physical location where the research will take place (if applicable). Include copies of any questionnaires, tests, or other written instruments, instructions, scripts, etc., to be used.



*Methods:*

This project will use data from a group intervention which was completed in a school located in the Stillwater school district. A total of 6 first grade students were part of the group intervention as part of their remediation plan determined by the student assistance team. Student performance was assessed before and after a 5 week intervention that used taped problems for quantity discrimination (QD). Student data will be analyzed and used in poster presentations at national conferences and be part of an article to be published in a national educational journal. This is to better inform the educational community on early numeracy skill intervention. Student data will be obtained from the school psychology office at the students school upon receiving parent permission and child assent to use their intervention data.

4. Will the subjects encounter the possibility of stress or psychological, social, physical, or legal risks that are greater than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests? ☐ Yes ☒ No

If Yes, please justify your position:

5. Will medical clearance be necessary for subjects to participate because of tissue or blood sampling, administration of substances such as food or drugs, or physical exercise conditioning? ☐ Yes ☒ No

If Yes, please explain how the clearance will be obtained:

6. Will the subjects be deceived or misled in any way? ☐ Yes ☒ No

If Yes, please explain:

7. Will information be requested that subjects might consider to be personal or sensitive? ☐ Yes ☒ No

If Yes, please explain:

8. Will the subjects be presented with materials that might be considered to be offensive, threatening, or degrading? ☐  
Yes ☒ No

If Yes, please explain, including measures planned for intervention if problems occur.

9. Will [any inducements](#) be offered to the subjects for their participation? Yes X No

If Yes, please explain:

NOTE: If extra course credit is offered, describe the alternative means for obtaining additional credit available to those students who do not wish to participate in the research project.

10. Describe the process to be used to obtain the [consent/assent](#) of all subjects including ([as appropriate](#)); who will seek the consent/assent, steps to minimize coercion or undue influence, and the method(s) to be used to document the consent.

**Please provide copies of all consent documents with your application**

Consent forms will be given to all possible participants in the project, which include the benefits and risks of participation (Appendix A). The form will be given to the classroom teachers to give to the parents. Forms will be sent home in the students' weekly folders. I will not include data from students whose parents returned forms indicating that they did not wish their children to participate.

11. Are you requesting a [waiver of documentation of consent](#) (no signature on consent/assent forms)? If you are conducting an anonymous survey, online or in paper form, check yes here.

☐ Yes X No

If yes, provide a justification for waiving documentation based on one of the [two criteria allowing the waiver](#).

12. Do you wish to waive of some of the [elements of consent/assent or parental permission](#) or the entire consent/assent or parent permission process?

☐ Yes X No

If yes, provide a justification for the waiver that addresses each of the [criteria](#) that must be met for the waiver to be allowed.

13. Will the data be a part of a [record that can be identified](#) with the subject?   X Yes   No

If Yes, please explain: A database will be set up to record data used in this project which will contain the id numbers of the students and will be stored on a password protected computer in the principal investigators office at Oklahoma State University that only they will have access to. Any data reported to the general public will be group data. Individual scores will not be disseminated nor will any identifying information (student, teacher, school, district) be made public.

In regard to the parent's access to student data: Parents who request information regarding their child will receive information concerning his/her math performance. Once student information is given to the parents, the identifiers will be removed from the database and student names will be replace by id numbers. Identifiers will remain with the data approximately 2 months after completion of the data collection.

14. Describe the steps you are taking to [protect the confidentiality of the subjects](#) and how you are going to advise subjects of these protections in the consent process. Include information on data storage and access. If data will not be reported in the form of group means, please explain how the data will be reported.

All personal information and scores collected during this project will be maintained in a password-protected database accessible only by project staff. If, as a result of this project a public presentation is created such as a journal publication or conference presentation, any identifiable information such as names would be replaced by their id number's to protect confidentiality of any participants. Completed math probes will remain in a locked file cabinet in Paul Hansmann's M.S. office.

15. Will the subject's participation in a specific experiment or study be made a part of any record available to his or her supervisor, teacher, or employer?   X Yes   ☐ No

If Yes, please describe: Results of the assessments conducted with students as well as any intervention results will be available to the student's teacher, school administration, and the student's legal guardian. Data collected for any given student will not be available to anyone who does not have a legal right to personal student information based on Public Law 93-830 (Family Educational Rights and Privacy Act). The data will not be used for any decisions

made regarding the student (class grades, standing in their class/grade, etc.) and will provide no potential risks to the student's academic progress.

16. Describe the benefits that might accrue to either the subjects or society. *Note that 45 CFR 46, Section 46.111(a)(2) requires that the risks to subjects be reasonable in relation to the anticipated benefits. The investigator should specifically state the importance of the knowledge that reasonably may be expected to result from this research.*

The current project will increase the literature on effective math interventions available to teachers and school psychologists. If a significant effect is found, the proposed intervention will offer an easy and time-efficient procedure to increase students' fluency in basic math skills.

#### **Application Submission:**

#### **Checklist for application submission:**

XCompletion of required IRB training (<http://compliance.vpr.okstate.edu/IRB/gs-CITI.aspx>)

☐ Grant Proposal, if research is externally funded

XOutline or script of information to be provided prior to subjects' agreement to participate

☐ Copies of flyers, announcements or other forms of recruitment

XInformed consent/assent forms

XInstrument(s) [questionnaire, survey, tests]

XResumes or CV's for all PIs (student or faculty) and advisors (4 page maximum for each)\*

\*CVs should highlight the education and research expertise of the researcher. Researchers may submit CVs prepared for federal

grant proposals (e.g., NIH, NSF, USDA, etc.).

#### **Appendices Included:**

☐ [Appendix A](#) - Request for OSU System Email Addresses for Human Subject Research

Recruitment Purposes

**Number of copies:**

**One (1), single sided** paper copy of the application and associated attachments, signed by all PIs and advisor (if appropriate). Scanned/faxed signatures are acceptable.

**Submission Address:**

IRB/University Research Compliance

Oklahoma State University

219 Cordell North

Stillwater, OK 74078-1038

**For assistance, please contact the IRB staff in the Office of University Research Compliance at 405-744-3377 or email [irb@okstate.edu](mailto:irb@okstate.edu).**

# Appendix D

$\begin{array}{r} 3 \\ +4 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ +2 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ +4 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ +1 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ +2 \\ \hline \end{array}$
$\begin{array}{r} 1 \\ +3 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ +2 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ +3 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ +4 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ +3 \\ \hline \end{array}$
$\begin{array}{r} 3 \\ +5 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ +5 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ +7 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ +1 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ +1 \\ \hline \end{array}$
$\begin{array}{r} 3 \\ +6 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ +7 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ +5 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ +1 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ +1 \\ \hline \end{array}$
$\begin{array}{r} 4 \\ +6 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ +2 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ +4 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ +2 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ +1 \\ \hline \end{array}$

# Appendix E

16—10	9 —16	9—19	9—3	14 —15
3 —16	15 —17	0—1	0 —15	14—1
17 —15	14—3	9—8	19—9	10—7
13 —12	14 —13	17—3	18—3	10—1
16 —20	15 —20	15—0	19—0	2—0

# Appendix F

$\begin{array}{c} 18 \\ 16 \swarrow \quad \searrow \\ \underline{19} \end{array}$	$\begin{array}{c} 7 \\ 2 \swarrow \quad \searrow \\ \underline{10} \end{array}$	$\begin{array}{c} 10 \\ 20 \swarrow \quad \searrow \\ \underline{14} \end{array}$	$\begin{array}{c} 8 \\ 9 \swarrow \quad \searrow \\ \underline{3} \end{array}$	$\begin{array}{c} 9 \\ 17 \swarrow \quad \searrow \\ \underline{0} \end{array}$
$\begin{array}{c} 18 \\ 6 \swarrow \quad \searrow \\ \underline{13} \end{array}$	$\begin{array}{c} 5 \\ 18 \swarrow \quad \searrow \\ \underline{3} \end{array}$	$\begin{array}{c} 13 \\ 18 \swarrow \quad \searrow \\ \underline{16} \end{array}$	$\begin{array}{c} 14 \\ 8 \swarrow \quad \searrow \\ \underline{13} \end{array}$	$\begin{array}{c} 10 \\ 4 \swarrow \quad \searrow \\ \underline{19} \end{array}$
$\begin{array}{c} 9 \\ 17 \swarrow \quad \searrow \\ \underline{7} \end{array}$	$\begin{array}{c} 17 \\ 16 \swarrow \quad \searrow \\ \underline{2} \end{array}$	$\begin{array}{c} 5 \\ 2 \swarrow \quad \searrow \\ \underline{14} \end{array}$	$\begin{array}{c} 7 \\ 19 \swarrow \quad \searrow \\ \underline{15} \end{array}$	$\begin{array}{c} 10 \\ 0 \swarrow \quad \searrow \\ \underline{\quad} \end{array} 11$
$\begin{array}{c} 14 \\ 19 \swarrow \quad \searrow \\ \underline{12} \end{array}$	$\begin{array}{c} 11 \\ 1 \swarrow \quad \searrow \\ \underline{19} \end{array}$	$\begin{array}{c} 4 \\ 16 \swarrow \quad \searrow \\ \underline{20} \end{array}$	$\begin{array}{c} 3 \\ 8 \swarrow \quad \searrow \\ \underline{16} \end{array}$	$\begin{array}{c} 10 \\ 17 \swarrow \quad \searrow \\ \underline{9} \end{array}$
$\begin{array}{c} 4 \\ 16 \swarrow \quad \searrow \\ \underline{11} \end{array}$	$\begin{array}{c} 18 \\ 20 \swarrow \quad \searrow \\ \underline{3} \end{array}$	$\begin{array}{c} 6 \\ 10 \swarrow \quad \searrow \\ \underline{0} \end{array}$	$\begin{array}{c} 14 \\ 12 \swarrow \quad \searrow \\ \underline{5} \end{array}$	$\begin{array}{c} 5 \\ 9 \swarrow \quad \searrow \\ \underline{0} \end{array}$
$\begin{array}{c} 18 \\ 11 \swarrow \quad \searrow \\ \underline{3} \end{array}$	$\begin{array}{c} 14 \\ 8 \swarrow \quad \searrow \\ \underline{7} \end{array}$	$\begin{array}{c} 13 \\ 18 \swarrow \quad \searrow \\ \underline{20} \end{array}$	$\begin{array}{c} 20 \\ 15 \swarrow \quad \searrow \\ \underline{2} \end{array}$	$\begin{array}{c} 8 \\ 7 \swarrow \quad \searrow \\ \underline{5} \end{array}$



## Appendix G

### Informed Consent Form Teacher

**Research study:** Early Numeracy Intervention: Does Quantity Discrimination Really Work?

**Investigators:** Paul Hansmann M.S., Brian Poncy, Ph.D.

**Purpose:** The purpose of this research study is to aid in the teaching of early math skills. I am working to develop a procedure that can be used in school by teachers to test and increase students early math skills. The skill of focus is identifying number size (identifying the bigger of two numbers). The purpose of this research study is to find whether intervening, on the ability of identifying number size among first grade students, will increase their math fact speed and overall math understanding.

**Procedures:** Students in this research study will be randomly assigned by class to 1 of 3 groups, groups 1 and 2 are described below. Group 3 is a control group and will not receive any teaching procedures only the assessments given before and after the teaching procedures are given to groups 1 and 2. Once the groups are established, students in groups 1 and 2 will be given one of two taped-problem procedures. The taped-problem procedures use a tape recorder to play audio recordings, which read a problem, gives a short time delay, then reads the answer. The study compares two types of procedures. The first procedure is a simple number size task, where the student chooses the larger of two numbers. For example the simple number size task will say “which number is bigger [12 or 7]”, provides a time delay, and then reads the answer “12”. The second is a complex number size task where the student chooses the closer of two numbers at the bottom of a triangle to the number at the top, or no intervention and will be used as a comparison group.



The complex number size task tape will ask, “Which number on the bottom is closer to the number at the top”, provides a time delay, and then reads the answer, for example “10”.

Comparing these two procedures will determine which one provides the best learning outcome for students. The procedures will take place in your student’s classroom and last 5 weeks with one 5-minute session taking place 5 days a week. Only students whom have had permission returned will have their data used in the study, those students from whom we have not received permission will not have their data used in this research study.

Your student will be given assessments to measure their math skills before and after the taped problems procedures are given in their classroom. This will determine the effectiveness of each procedure. The first measure will be an addition worksheet maximum answer of 10. Your student will be given one minute to complete as many problems as he/she can during the one minute timing. The second measure will be a worksheet with addition and subtraction problems

and be given 3 minutes to complete as many problems as they can. This worksheet will range from simple ( $1+1=2$  and  $3-2=1$ ) problems to the most difficult being ( $13+7=20$  and  $20-9=11$ ). These two worksheets will allow us to see how fast your student can complete math problems of varying difficulty. The third is a Number Knowledge measure which has a series of questions asking your student to compute addition and subtraction problems, identifying which number is larger, and answering word problems. This will allow us to determine your student's overall math skill. Your student will also be given two worksheets made up of each type of problem from the teaching procedures to show their growth before and after the classroom procedures are given.

By signing, you are giving permission for your student to participate in this research study as well as permission to have their data available for future publication after the study is over. Your student's identity will be kept confidential at all times during the research study through the use of an ID number, which will be given to your student at the beginning of the research study. If you do not provide permission your student's data will not be used for the research study. However all students will receive the class teaching procedure.

**Risks of Participation:** There are few to no risks of participation in this research study as the target behavior (computation of basic math facts) and procedures are similar to those used in the general education setting. The student's personal information will remain confidential. Data that is collected from individual students will be averaged into an overall class average to prevent individual scores from being seen. Upon request the teacher and or parent(s) of the student can have access to both individual and/or group data. Student name's will not be used at anytime during this research study. Only the id numbers we provide after collecting student assent forms will be associated with the data.

In regard to the principal's, teacher's, and parent's access to student data: The principal and teacher will be given information in the form of a graph of the aggregated performance of the group and a table with the means of student performance in digits correct per minute data from the assessment phases. Parents who request information regarding their student will also receive information concerning his/her math performance. Once student information is given to the principal, teacher, and parents, the identifiers will be removed from the database and student names will be replaced by ID numbers. Identifiers will remain with the data approximately 2 months after completion of the data collection.

**Benefits:** The information your student's provides will assist us in better developing more efficient and effective procedures for teaching early math skills to public school students. Similar use of these procedures has proven to work to increase math fluency and accuracy in students and will likely confer benefit on the students who participate in the research study. This will result in your students being able to quickly and accurately complete basic fact problems.

**Confidentiality:** Your student's identity will be linked with information collected in this research study through the use of research ID numbers. Students will be given ID numbers and data will be stored under the student's ID number in the principal investigators office on compact discs in a locked cabinet at Oklahoma State University or in password-protected electronic files on the principal investigator's university computer. Only the principal investigator and graduate student

assistants will have access to the data. A list linking names to ID numbers will be maintained to provide information to parents upon request. Once this has happened, the list will be destroyed. Data will be stored for five years after the research study is complete, and then destroyed. The information obtained in this research study will be reported only in aggregated form and may be published in scientific journals or presented at scientific meetings. The Oklahoma State University Institutional Review Board has the authority to inspect consent records and data files to assure compliance with approved procedures.

**Contacts:** You may ask questions regarding this research and have these questions answered before agreeing to participate in the research study. You may also ask questions during the research study. You may call the primary investigator Paul Hansmann M.S., (405) 744-4802, or his advisor Dr. Brian Poncy, (405) 744-4808 at any time to discuss this research. If you have any questions about the research and your rights as a research volunteer, you may contact Dr. Shelia Kennison, IRB Chair, 219 Cordell North, (405) 744-3377 or [irb@okstate.edu](mailto:irb@okstate.edu).

**Participants' Rights:** You are free to decide whether or not your students will participate in this research study or to withdraw their participation at any time without reprisal or penalty.

**Please check one box below and return in the enclosed envelope.** Thank you.

I have read and fully understand this information.

☐ **I DO**

☐ **I DO NOT**

**Agree to allow the students in my classroom to participate in this research study**

---

Teacher's name (please print)

---

Teacher's Signature

---

Date

Paul Hansmann, M.S.  
Graduate Student OSU  
Primary Investigator  
School Psychology

Dr. Brian Poncy Ph.D.  
Assistant Prof. OSU  
Advisor of Primary Investigator  
School Psychology

## Appendix H

### Informed Consent Form Principal

**Project:** Early Numeracy Intervention: Does Quantity Discrimination Really Work?

**Investigators:** Paul Hansmann M.S., Brian Poncy, Ph.D.

**Purpose:** The purpose of this research study is to aid in the teaching of early math skills. I am working to develop a procedure that can be used in school by teachers to test and increase students early math skills. The skill of focus is identifying number size (identifying the bigger of two numbers). The purpose of this research study is to find whether intervening, on the ability of identifying number size among first grade students, will increase their math fact speed and overall math understanding.

**Procedures:** Students in this research study will be randomly assigned by class to 1 of 3 groups, groups 1 and 2 are described below. Group 3 is a control group and will not receive any teaching procedures only the assessments given before and after the teaching procedures are given to groups 1 and 2. Once the groups are established, students in groups 1 and 2 will be given one of two taped-problem procedures. The taped-problem procedures use a tape recorder to play audio recordings, which read a problem, gives a short time delay, then reads the answer. The study compares two types of procedures. The first procedure is a simple number size task, where the student chooses the larger of two numbers. For example the simple number size task will say “which number is bigger [12 or 7]”, provides a time delay, and then reads the answer “12”. The second is a complex number size task where the student chooses the closer of two numbers at the bottom of a triangle to the number at the top, or no intervention and will be used as a comparison group.



The complex number size task tape will ask, “Which number on the bottom is closer to the number at the top”, provides a time delay, and then reads the answer, for example “10”.

Comparing these two procedures will determine which one provides the best learning outcome for students. The procedures will take place in your student’s classroom and last 5 weeks with one 5-minute session taking place 5 days a week. Only students whom have had permission returned will have their data used in the study, those students from whom we have not received permission will not have their data used in this research study.

Your student will be given assessments to measure their math skills before and after the taped problems procedures are given in their classroom. This will determine the effectiveness of each procedure. The first measure will be an addition worksheet maximum answer of 10. Your student will be given one minute to complete as many problems as he/she can during the one minute timing. The second measure will be a worksheet with addition and subtraction problems

and be given 3 minutes to complete as many problems as they can. This worksheet will range from simple ( $1+1=2$  and  $3-2=1$ ) problems to the most difficult being ( $13+7=20$  and  $20-9=11$ ). These two worksheets will allow us to see how fast your student can complete math problems of varying difficulty. The third is a Number Knowledge measure which has a series of questions asking your student to compute addition and subtraction problems, identifying which number is larger, and answering word problems. This will allow us to determine your student's overall math skill. Your student will also be given two worksheets made up of each type of problem from the teaching procedures to show their growth before and after the classroom procedures are given.

By signing, you are giving permission for your student to participate in this research study as well as permission to have their data available for future publication after the study is over. Your student's identity will be kept confidential at all times during the research study through the use of an ID number, which will be given to your student at the beginning of the research study. If you do not provide permission your student's data will not be used for the research study. However all students will receive the class teaching procedure.

**Risks of Participation:** There are few to no risks of participation in this research study as the target behavior (computation of basic math facts) and procedures are similar to those used in the general education setting. The student's personal information will remain confidential. Data that is collected from individual students will be averaged into an overall class average to prevent individual scores from being seen. Upon request the teacher and or parent(s) of the student can have access to both individual and/or group data. Student name's will not be used at anytime during this research study. Only the id numbers we provide after collecting student assent forms will be associated with the data.

In regard to the principal's, teacher's, and parent's access to student data: The principal and teacher will be given information in the form of a graph of the aggregated performance of the group and a table with the means of student performance in digits correct per minute data from the assessment phases. Parents who request information regarding their student will also receive information concerning his/her math performance. Once student information is given to the principal, teacher, and parents, the identifiers will be removed from the database and student names will be replaced by ID numbers. Identifiers will remain with the data approximately 2 months after completion of the data collection.

**Benefits:** The information your student's provides will assist us in better developing more efficient and effective procedures for teaching early math skills to public school students. Similar use of these procedures has proven to work to increase math fluency and accuracy in students and will likely confer benefit on the students who participate in the research study. This will result in your students being able to quickly and accurately complete basic fact problems.

**Confidentiality:** Your student's identity will be linked with information collected in this research study through the use of research ID numbers. Students will be given ID numbers and data will be stored under the student's ID number in the principal investigators office on compact discs in a locked cabinet at Oklahoma State University or in password-protected electronic files on the principal investigator's university computer. Only the principal investigator and graduate student

assistants will have access to the data. A list linking names to ID numbers will be maintained to provide information to parents upon request. Once this has happened, the list will be destroyed. Data will be stored for five years after the research study is complete, and then destroyed. The information obtained in this research study will be reported only in aggregated form and may be published in scientific journals or presented at scientific meetings. The Oklahoma State University Institutional Review Board has the authority to inspect consent records and data files to assure compliance with approved procedures.

**Contacts:** You may ask questions regarding this research and have these questions answered before agreeing to participate in the research study. You may also ask questions during the research study. You may call the primary investigator Paul Hansmann M.S., (405) 744-4802, or his advisor Dr. Brian Poncy, (405) 744-4808 at any time to discuss this research. If you have any questions about the research and your rights as a research volunteer, you may contact Dr. Shelia Kennison, IRB Chair, 219 Cordell North, (405) 744-3377 or [irb@okstate.edu](mailto:irb@okstate.edu).

**Participants' Rights:** You are free to decide whether or not your students will participate in this research study or to withdraw their participation at any time without reprisal or penalty.

I have read and fully understand this information.

☐ **I DO**

☐ **I DO NOT**

**Agree to allow the students in my classroom to participate in this research study.**

---

Teacher's name (please print)

---

Teacher's Signature

---

Date

Paul Hansmann, M.S.  
Graduate Student OSU  
Primary Investigator  
School Psychology

Dr. Brian Poncy Ph.D.  
Assistant Prof. OSU  
Advisor of Primary Investigator  
School Psychology

## Appendix I

Figure 1 without 18 students

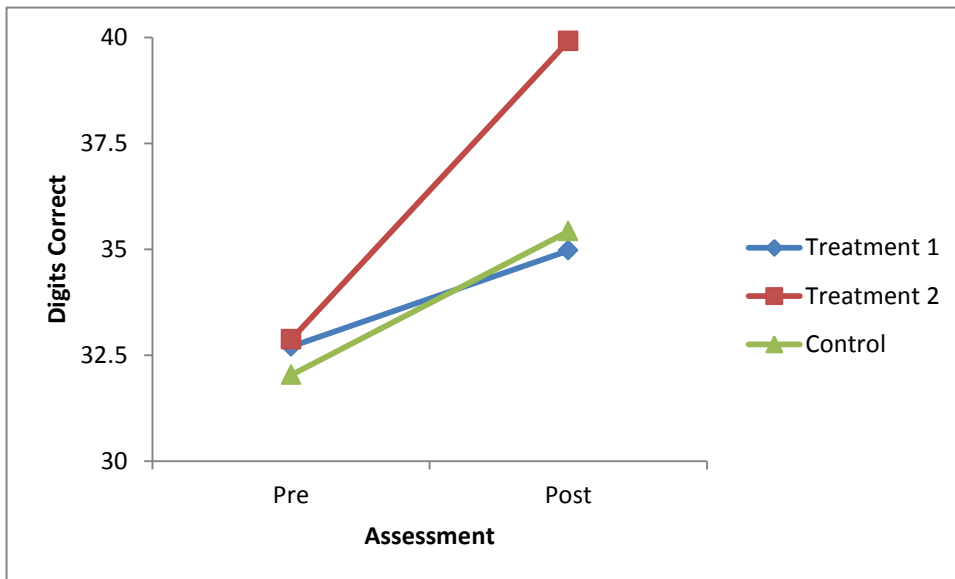


Figure 5

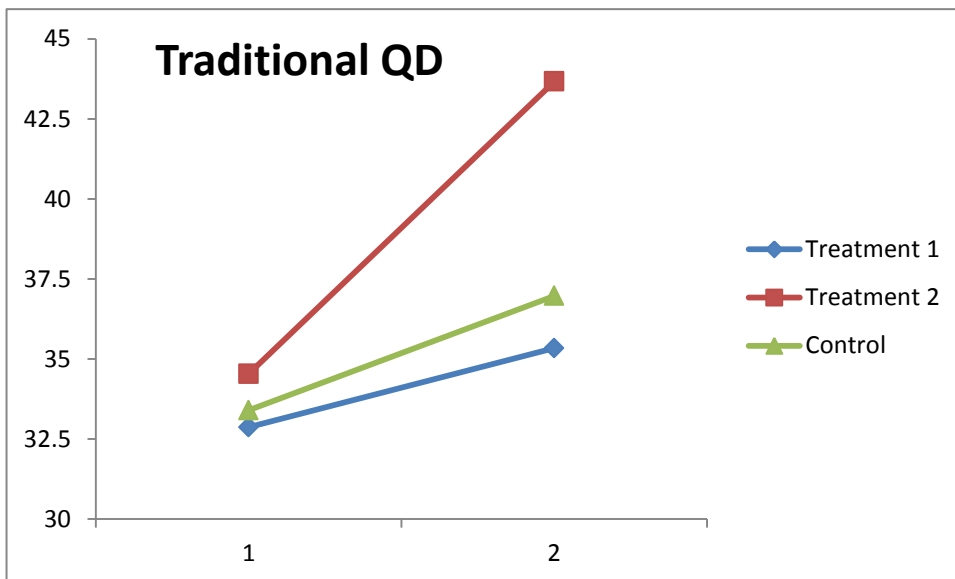


Figure 2 without 18 students

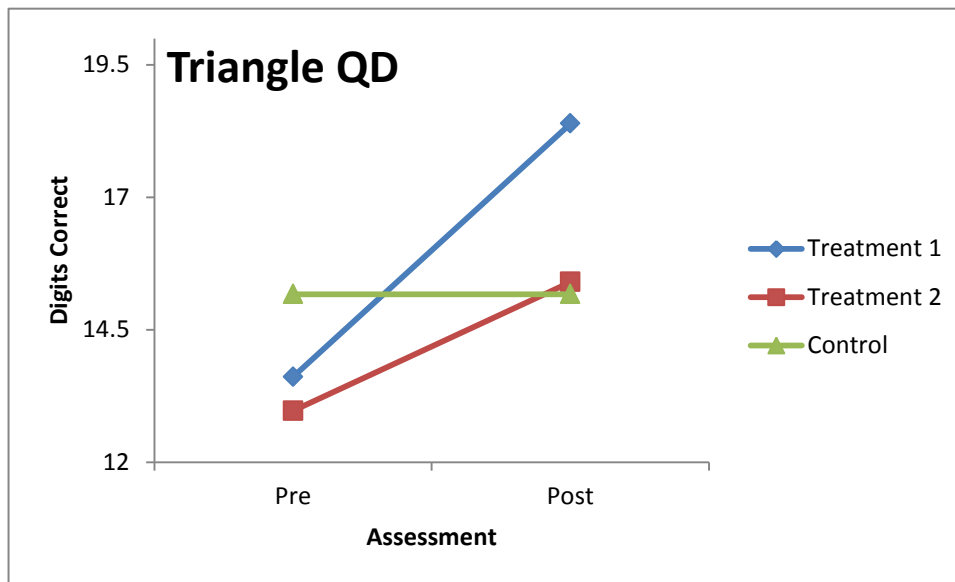


Figure 6

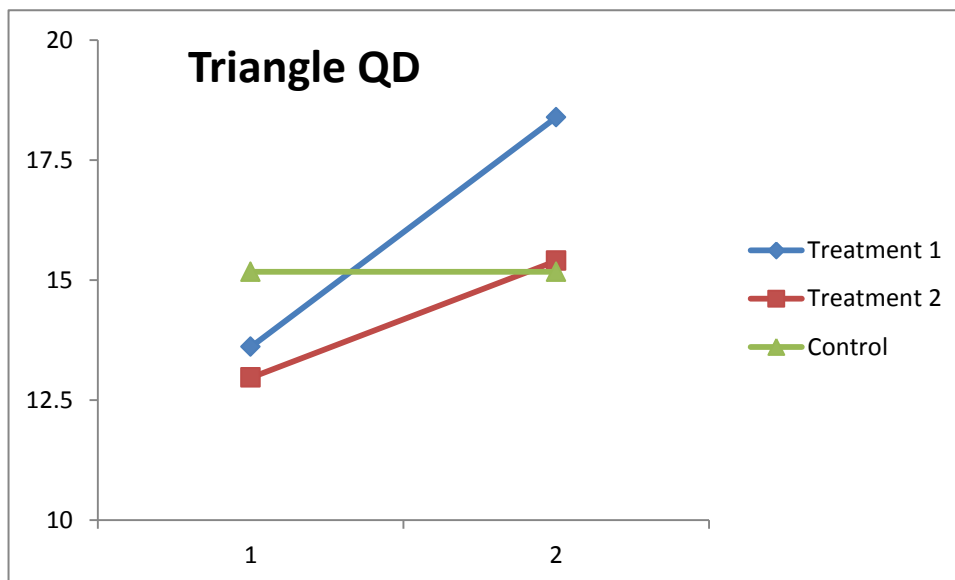




Figure 3 without 18 students

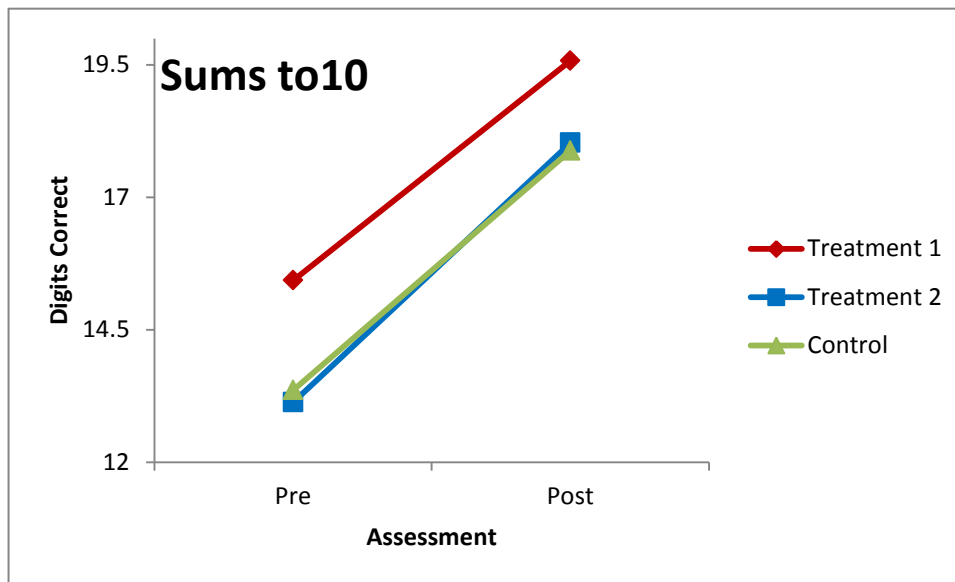


Figure 7

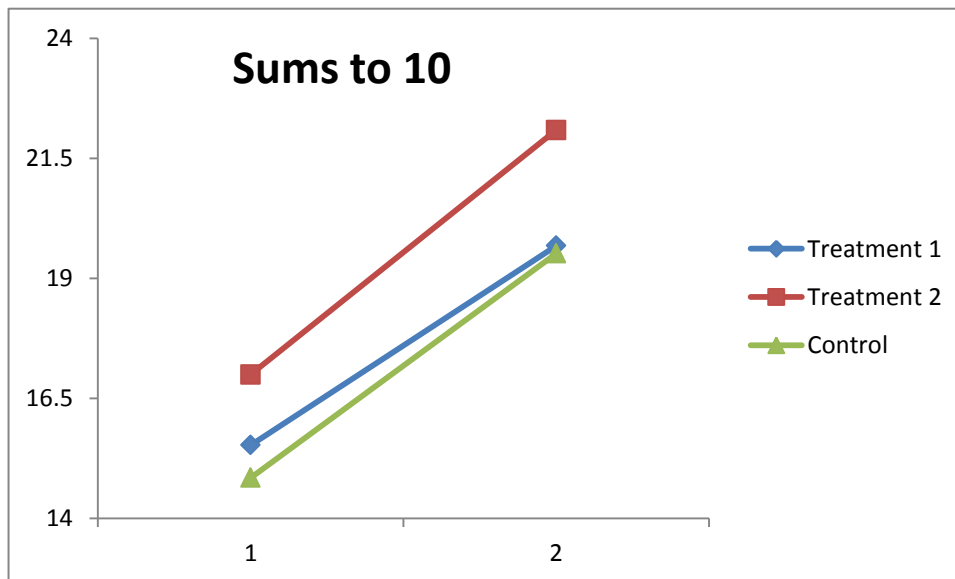


Figure 4 without 18 students

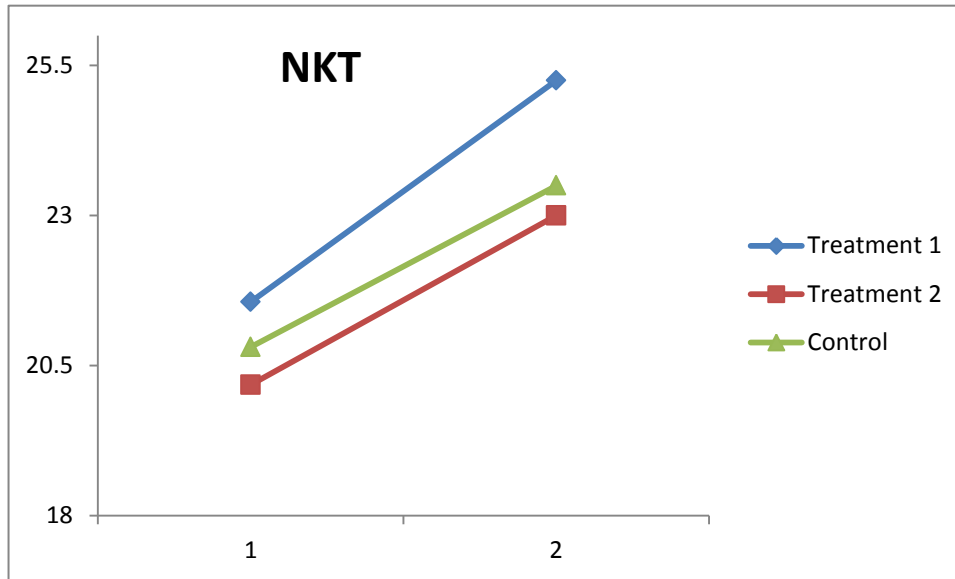
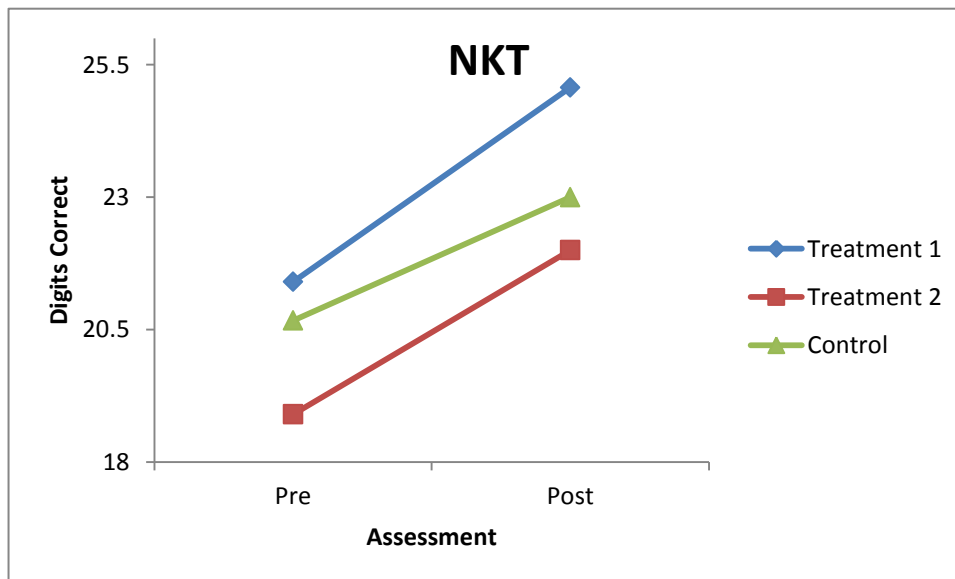


Figure 8



## APPENDIX J

### Oklahoma State University Institutional Review Board

Date: Thursday, November 17, 2011

IRB Application No ED11172

Proposal Title: Early Numeracy Intervention: Does quantity discrimination really work?

Reviewed and Expedited  
Processed as:

**Status Recommended by Reviewer(s): Approved Protocol Expires: 11/16/2012**

Principal  
Investigator(s):

Paul Hansmann  
447 Willard  
Stillwater, OK 74078

Brian C. Poncy  
420 Willard  
Stillwater, OK 74078

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The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

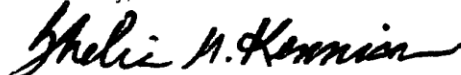
☒ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Beth McTernan in 219 Cordell North (phone: 405-744-5700, beth.mcternan@okstate.edu).

Sincerely,



Shelia Kennison, Chair  
Institutional Review Board

## VITA

Paul Richard Hansmann

Candidate for the Degree of

Doctor of Philosophy/Education

Thesis: **EARLY NUMERACY INTERVENTION: DOES QUANTITY  
DISCRIMINATION REALLY WORK?**

Major Field: Educational Psychology

Biographical:

Education:

Completed the requirements for the Doctor of Philosophy in Educational Psychology at Oklahoma State University, Stillwater, OK in May, 2013.

Completed the requirements for the Master of Science in Educational Psychology at Oklahoma State University, Stillwater, OK in 2010.

Completed the requirements for the Bachelor of Arts in Psychology at The University of Montana, Missoula, MT in 2008.

Experience: Fall 2012-Summer 2013 School Psychology Pre-Doctoral Internship (1500 hours)  
Fall 2011-Spring 2012 Doctoral Practicum (400 hours)  
Fall 2010-Spring 2011 School Based Practicum (844 hours)  
Fall 2010-Spring 2011 Therapy Practicum (140 hours)  
Fall 2009-Spring 2010 Shadow Practicum (240 hours)

Professional Memberships: School Psychology Graduate Organization  
Oklahoma School Psychology Association  
American Psychological Association, div. 16  
National Association of School Psychology